The Knowledge Seekers

How to **Turn your Community** into an Engine for **Economic Success**

W. Arthur Porter, Ph.D.

THE KNOWLEDGE SEEKERS

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The ability to create technology, turn it into a product, and get value from it will determine success in the 21st century.

IC2 INSTITUTE
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I dedicate this book to the
memory of my mother and father
who taught me the value of
learning, anticipating, initiating,
and adapting—and to always
do them with integrity.

W. Arthur Porter

The difference between creating jobs and creating wealth is knowledge. Knowledge is now the driver of our economy. To gain a competitive advantage in a changing global economy, we must learn how to leverage our intellectual resources.

W. Arthur Porter

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FOREWORD

We have enjoyed the first part of the "new economy" technology revolution–information technology. We now are in a second and I believe more critical phase–the digital knowledge economy. In this new phase, the wealth creation network concept undertakes a more important, long-term contribution to society.

Dr. W. Arthur "Skip" Porter is a great friend and colleague who has an even greater passion and vision for this second-generation new economy. He believes the tenant of success is linking knowledge and talent from the four corners of academia with the vision and capital in the private sector. We share a common goal: to move ideas from concept to the marketplace faster, more efficiently, and with greater return on investment.

To accomplish this goal means changing the 20th century "linear" system of research and development to a 21st century societal value creation that starts from ground zero the day that a research program starts. That's why it takes someone with Skip's level of practical insight, fervent evangelism, business acumen, and sense of humor to bring these entrenched forces together.

It has been my pleasure to have Skip as a colleague for the past three decades in developing commercialization of sci-

ence and technology as a major driver for wealth creation and prosperity sharing. He has been a big help to me, especially to understand that we must address three key issues:

First. Provide entrepreneurial leadership at the community level. This leadership must be caring and sharing. Therefore, this leadership must come from within the community.

Second. The community leadership must provide for a proactive research base, which must stay on the cutting edge of commercializing technology for the emerging global markets, including building global alliances.

Third. Improve work force development programs for entry skills, technicians, and the science, engineering, and management professions.

All individuals need to have opportunities–jobs, skills, and competencies–as well as appropriate recognition of their contributions. The community leadership needs to integrate its economic, cultural, political, and technology sectors. Entrepreneurial community leadership must come from partnerships of the academic, business, government, and foundation sectors.

As always, I'd like to quote my good friend, Dr. Skip Porter:

> I challenge you to not just read this book. Put it into
>
> The richness of a community is no longer tied to natural resources or the industrial base, but to how well its leadership takes advantage of human potential. A community's ability to learn not only how to create technology, but also how to turn it

> into a product and gain value from it will be the test that determines success in the 21st century.

practice in the communities where you live. Let it change your approach to generating wealth and sharing prosperity. Get excited about the potential of ushering in a new mindset that can make an impact for future generations.

George Kozmetsky, Ph.D.
Chairman, The IC² Institute
University of Texas at Austin

PUBLISHER'S MESSAGE

THE CONTEXT: TECHNOPOLIS FACILITATING ORGANIZATIONS

This IC^2 Fellows Book describes a new, collaborative kind of institution to speed technology innovations–Centers for the Performing Sciences. These Centers help communities become part of the 21st century's renaissance in technology.

What does this "techno-renaissance" mean for our future? It will bring momentous change in nearly all aspects of life. We can already see the beginnings of some of these changes that make our lives better and richer in every sense . . . from the continuing defeat of diseases that cut precious lives short . . . to such mundane but helpful advances as how the internet will make possible overnight car repairs with free pick-up and delivery . . . to machine computer languages that will permit translations of human languages as diverse as Japanese or Swahili in real time.

But some changes will be unsettling as we seek to protect our jobs, our environment, sometimes our very way of

life. Differing views can be expected, encouraged, and even embraced, for the absence of such frictions indicates an equilibrium of stagnation.

As we look beyond 2010, new technology developments become increasingly speculative. However, "speculation" itself implies possibility and, with enough time, amazing changes indeed will be possible.

For instance, advances in our knowledge of cell life will make possible longer, healthy life spans in the not too distant future. While you may not want to live 150 years or more, scientists are beginning to talk of life spans in these terms. The point is, healthy centenarians will not only be commonplace by the next century, they will very likely be a significant share of a nation's population.

On the economic front, the techno-renaissance will have an equally startling impact in the next 100 years. It may mean the end of economic scarcity. That may sound outlandish or even "pollyannaish" to some. But wait a moment. Just think how far we have come in the last 125 years. Imagine people who lived from 1800 to 1875 returning today to a developed country. What would they see? They would be astounded by the changes in health, life expectancy, transportation, housing, communications, education, and the countless innovations that routinely shape our lives every day.

To be fair, our transported visitors wouldn't see only the good things produced by technology. The nightmare applications of technology for human and environmental destruction might literally threaten our visitors' sanity. Aside from the horrific, our visitors might also see that many positive advances produced by technology have not benefited

everyone. At most, these changes have affected no more than 1 billion of the world's 6 billion people. For the less fortunate 5 billion, life wouldn't be all that different from life in 1875 with the possible exception that through a village TV or movie house, they would know something definitely better exists. Such knowledge can't help but breed the seeds of social turmoil.

If the renaissance in technology is sustained, can we close this gap in the sharing of technology's benefits? No one can say for sure, but we believe wealth creation and equitable wealth distribution can take quantum leaps if the right institutional innovations are discovered and implemented over the next few decades. As scientific knowledge increases and multiplies, a critical issue is how rapidly and effectively this research can be transferred into personal and community wealth. Our thesis at IC^2 is that the "technology divide" will be bridged only with the creative innovation of institutions that leverage the wealth creating/wealth sharing process in ways yet unforeseen or yet adopted.

At IC^2, we call these new institutions, for want of a better name, technopolis facilitating organizations. Today, we know that a disproportionate share of the new wealth is coming from technology-intensive cities and regions. Silicon Valley, Austin, and Boston's Route 128 are well-known examples. But scores of techno-regions are emerging around the world. How quickly and successfully these wealth-producing regions emerge will determine our future–not just our economic future, but also our social and political futures. Will war and other institutionalized evils afflicting mankind ever be abolished as long as economic scarcity exists? I doubt it.

Fortunately, I have far less doubt about the positive role technopolis-facilitating organizations can play in the future. Sure, I have my doubts about the efficacy of these new institutions. After all, the evidence is slim. But what is available suggests that technopolis-facilitating organizations indeed accelerate the wealth creation process, and increase per capita GDP.

All of this discourse is context for Dr. W. Arthur Porter's insightful and concise book about a particular kind of technopolis-facilitating organization that he calls "Centers for the Performing Sciences." Without this overview, my fear is that readers would simply not appreciate the great significance of his wonderful work.

In addition, I wish to support Dr. Porter's work with three recommendations. First, Centers for the Performing Sciences need to be widely adopted because they accelerate the wealth creation process. Second, we need to understand how these Centers function, and how we can improve them, much the way we understand how venture incubators function. Third, Centers for the Performing Sciences should be combined with other kinds of technopolis-facilitating organizations that specialize in fostering technology commercialization and high-growth entrepreneurship. My rationale for these mergers is speculative, but I believe a critical mass of resources is needed to bring research from the laboratory to the marketplace. The investment in these larger organizations, much like the returns on venture capital, will be more than justified by the wealth they create.

We have learned much about entrepreneurship and venture commercialization over the past 30 years. But we still

know precious little about the process that improves our efficiency and effectiveness regarding the transfer of raw science and ideas into viable technology and commercial products that can both create new wealth and improve the human condition. Dr. Porter's institutional concept of Centers for the Performance Sciences moves us ahead. Like all the IC² Books, it is limited in words, but powerful in insight.

Dr. Robert Ronstadt
Director, IC² Institute

PREFACE

The world is a vastly different place than it was during the post-WWII years of my childhood in Irving, Texas. Growing up in and around my father's shoe repair shop, I spent my Saturdays riding past fields of cotton and cattle during our ritual, cross-country trip to Tandy in Fort Worth to buy cowhides. Tandy sold leather, not electronics, and Radio Shack didn't yet exist. Summer weekdays were easily spent listening to the idle chatter of townsfolk at the local drug store.

In those days, the talk would drift from town gossip and politics to weather and the price of crops. Whenever the community faced a period of turmoil or change, the old-timers would shake their heads and say to one another, "I'll be glad when this is over so we can get back to business as usual."

That bucolic little North Texas town has been swallowed by the urban sprawl of the Dallas–Fort Worth metroplex. A drive to Fort Worth now takes you through the neighborhood of several million people. You'd be hard-pressed to find a cotton field along the way. People chatting

on the square in modern Irving are more apt to talk about the price of computers than livestock. Their shoes are more likely made in an automated factory in Taiwan than in Texas, much less a little cobbler shop in Irving. Today, the financial well-being of my hometown–like that of every other community in the world–has become entangled in an increasingly global, technologically driven marketplace.

Occasionally, I still hear people yearning for a return to "business as usual." But most people are coming to the conclusion that our society is in the midst of rapid and irreversible change. They are recognizing that a fundamental shift is happening:

"Business as usual" is out of business!

Many who recognize this shift are searching for ways to use it for the benefit of their communities. They realize, I believe correctly, that communities that adapt will be the ones that thrive in the emerging knowledge-based economy. But even these perceptive leaders can be overwhelmed by the scale and the uncertainty of the actions needed to tap into this new economy.

This growing realization of the need for change has led many people from the United States and around the world to the Houston Advanced Research Center (HARC) as they search for new models for lasting economic development. It is for these people, and others like them, that I have written this book; and the reason that I am now at the University of Oklahoma helping Oklahoma address these same issues.

Many are in the same situation as those leaders a century ago who saw the arrival of the automobile and recognized the beginning of a new industrial age. They didn't know

exactly what was coming, but they knew it could bring prosperity if they could get a piece of it for their own communities. Those communities that created the right environment for industrial development were the big winners of the 20th century. However, 20th century rules no longer apply in an economy driven by intellectual products.

When our quality of life was based on what we raised or grew on the land, the U.S. government created the Morrill Act and the land grant university system for agricultural research and extension services to provide support. As our quality of life began to depend primarily on industry and what was manufactured in steel and automobile and other factories, we created engineering research and extension services to support industry. Now, as we move into an era where our quality of life depends on intellectual products and our ability to use them, what do we do to stimulate and support this new kind of knowledge-based economy?

After more than 30 years of working in private industry, government, and academia, I have concluded that our society's existing institutions are basically unsuited to respond to our new economic needs. Any community that wants to be competitive in, and help shape, this technologically driven, global economy will not succeed by simply relying on their universities, governments, and businesses as they now function. They must create new mechanisms combining talent from industry, academia, and government to develop new technologies and move science-based products into the marketplace, with the community benefiting from the value created. I call these places, these mechanisms, "Centers for the Performing Sciences."

At HARC, I was involved in one of the earliest experiments to create this kind of a center. HARC was a unique idea when it was founded in 1982 as a privately funded institution. Modeled after the Research Triangle Institute, its mission was to move new discoveries out of the laboratories of academic institutions and link these discoveries with industry and government talent to create successful new-technology products and services. I've seen the challenges that communities face in trying to establish a technology center that can help the community succeed economically.

In an editorial in Science, Neil Lane, a good friend and a former director of HARC, and science advisor to President Clinton, recalls the quote, "Good judgment is a matter of experience and experience is only gained from bad judgment." My understanding of the process for creating a Center for the Performing Sciences now has the benefit of more than a decade of experience, so I must have achieved a high level of good judgment, which means, of course, I've made my share of bad judgments!

I hope to share with you some of the lessons I've learned through the years leading up to and creating a Center for the Performing Sciences in Texas, my observations of how such institutions benefit their communities, the university's role in the new economy, and a changing federal laboratory scene. Also, I will explore the changing strategies for research and development in some of our largest industries, as well as what we are now doing in Oklahoma.

In this book, I also hope to provide tools that readers can use to begin the process of developing technology centers in their communities. Unfortunately, there is no simple formula or recipe. Creating a Center for the Performing Sciences will require a community's commitment and investment, much

like the commitment needed to start a new company. The community's location, resources, and its culture all play significant roles. And what succeeds in one place may fail in another. Don't expect plug and play!

This book results from the work of many people. I thank first George Mitchell for the courage to start HARC and for encouraging me to write about it. And I thank George Kozmetsky for the years of collaboration on many related projects and his support and help in writing this book. I am fortunate to have them as friends. Finally, I want to thank Barbara Peyton, a HARC colleague, and Gregor Rae, a trusted friend and founder of BusinessLab in Aberdeen, Scotland, whose steady support, probing minds, and get-it-done attitude kept the project on track to completion.

My hope is that this book will offer a clear understanding of the cultural and academic issues involved, and practical guidance for business, political, and community leaders working to create new-technology Centers. I have tried not to write a book about science, because scientists usually are not the driving forces behind the creation of such Centers. Instead, I have attempted to be brief and nonacademic, using analogies and stories from my experiences to support conclusions that I believe have broad application.

Most of all, I hope that readers will be inspired to support the creation of science-based business in their communities and that, one day, many communities will benefit from their own Centers for the Performing Sciences.

W. Arthur Porter

Note: I would be pleased to have readers' thoughts and to begin a dialog about the ideas in this book. Contact me at: porter@ou.edu.

PROLOGUE

A TREE GROWS IN SCOTLAND

I first visited the Houston Advanced Research Center in 1988 as part of an international research program my organization was leading into the competitive strategies of cities, states, and nations.

We were particularly interested in the link between economic strategy and regional marketing, the role of public- and private-sector partnerships and the key vehicles communities were developing to enhance competitive position. The work involved studies of major initiatives in the United Kingdom, France, Germany, Scandinavia, the Far East, Canada and, of course, the United States (which, in our opinion, was leading the world in this area).

HARC came up on our radar screen very early in our investigations into the diversification strategy of Houston in the 1980s. I heard a Texas energy baron, George Mitchell, had created a new, innovative, collaborative research center at the heart of a new community to the north of Houston. I also heard that it was led by a visionary, entrepreneurial

professor, W. Arthur "Skip" Porter, and I wanted to know more.

As fate would have it, in May 1988 our work took us to the Lone Star State to speak to the Houston Economic Development Council. Someone knew someone at HARC and a call was put in to introduce me. Then, one fine May morning, I found myself in the Woodlands driving along the spectacular Research Forest Drive.

I turned into the HARC campus. It was stunning. The architecture was somehow perfectly in tune with its environment. Indeed, as I later discovered, the architecture plays a central part in the HARC concept.

Once inside the main building, I walked along a cavernous, post-modern corridor to a central atrium. As a student of architecture I was impressed by the striking use of materials, colors, and the abundance of natural light. In this carefully crafted blend of the ancient and the modern, I knew I was in a unique space. It was a sensation I will never forget. At this point a seed was sown in a distant Scottish landscape.

I was taken to the first floor, past a supercomputer center that was silently churning out data, surrounded by a group of people. They looked like a team of students, professors, and business people. The atmosphere was charged with a sense of focus and creativity that I'd not sensed anywhere before.

I was led through an anteroom into a large empty office. It was serene. The design was classical. It was international–Japanese, North American, Chinese, European, Scandinavian. Lining the walls were framed awards and

photographs of many people I recognized and admired: politicians, scientists, and business leaders.

I turned, and was truly taken aback. There, on the wall to my left, hung a huge oil painting of a scene I knew well. Here, in the heat and humidity of a Texas spring morning I was looking up at the Great Glen. The light shone through the window, lighting the picture as the artist had seen it. A single beam of light crossed the room and fell onto the bothy at the center of the impressive canvas.

"I've been in that bothy!" said I, aware that a tall, slim figure was entering the room. "So have I, laddie," came the reply. "So have I." There was a warm laugh. I had met Skip Porter. And I was about to start to learn about a new way of doing business. Correction: THE new way of doing business.

The HARC philosophy is about bringing the best minds together, from wherever on the planet, to innovate; to create; to push the envelope within an environment that encourages spirited collaboration. In this Center for the Performing Sciences technology, talent–the "two percenters" as Porter refers to them–and teamwork come together in a heady mix.

On top of that I learned that Porter had amassed an international network of friends, supporters, and advisers for the Center. HARC's roots might have been in the fertile Texas soil of the Woodlands forest, but its vision was truly global. And it had a bold vision.

Since that day in 1988, HARC and Porter's philosophy has had a huge influence in my own views of how an organization can and should work. For over 10 years I made the regular pilgrimage to the Woodlands. Each time I was

welcomed as a friend, and each time I left inspired and determined to attempt to apply what I had learned there.

Collaboration, creativity, and partnership are words that trip off the tongue very easily. And many organizations in the public and the private sector use them to describe their approach. But sadly, in all too many cases, it goes no further than the words. Blinkered, self-interest prevails. Mediocrity results.

Trying to build an effective business model around these values is not easy, and few organizations or communities can make it work. Anyone wishing to develop the art could do no better than to look at what Skip Porter achieved at HARC, and learn.

I hope we have. In our own way we are, thirteen years after that first visit to the Woodlands, embarking on the creation of a Scottish version of HARC. In collaboration with the Scottish government, and working with a number of leading universities, we have been creating a national resource for Scotland, a Center where civil servants, academics, and business leaders feel equally at home. This special place is where the best minds, young and old, come together to address some of the big issues facing our communities and our organizations, to develop truly innovative solutions.

The seed from Houston has become a sapling in Scotland. Time will tell if we're enjoying the birth of a new Caledonian Forest.

Gregor F. Rae
Co-founder and Director
BusinessLab

CHAPTER ONE

A NEW CULTURE

The knowledge society will inevitably become far more competitive than any society we have yet known — for the simple reason that with knowledge being universally accessible, there will be no excuses for non-performance. There will be no "poor" countries. There will only be ignorant countries.

Peter F. Drucker

Never in the history of the world has the product of greatest value been so easy to move. When we were shipping silks and spices, timber and ivory across oceans, it was the great port cities where commerce grew. Those cities grew rich and grand and lured many voyagers to them hoping for personal wealth. One of President Jefferson's reasons for undertaking the Lewis and Clark Expedition was to find a waterway to the Pacific so this nation could compete for Asia's trade.

Today, any community can be a port city because the product of greatest value is what comes from the human mind–our intellect.

KNOWLEDGE

Knowledge is the new national resource, and transmission of that most valuable resource now moves instantaneously. You do not need to load the formula for a cancer treatment, or the design for a new engine, or the business model for a new e-business on an airplane or a truck to move it. You simply move intellectual products and properties across the internet or a fax line. Instantaneously.

As each day passes, I see a growing global realization that intellectual property is the key product of the new millennium. The ability to create technology, turn it into a product, and gain value from it will determine success in the 21st century.

For many communities this involves putting in place the "missing piece," the infrastructure or "port" where intellectual property can be shipped commercially. I call this missing piece the Center for the Performing Sciences. In this book I've tried to capture the lessons learned through the creation and the development of the Houston Advanced Research Center (HARC), a Center for the Performing Sciences in Texas. These observations include how similar institutions have fared, the university's role in the new economy, and the effect of a changing federal laboratory mission in the United States. Also, I explore some of the changes that even the largest industries are undergoing with respect to research and development, and how they can benefit from a Center for the Performing Sciences. Such Centers become the missing link between the research laboratory and the marketplace by providing opportunities for collaborative efforts that

can greatly increase the capability for creating intellectual properties.

Leaders from all over the world have visited HARC. They want to know how, what, and why. They want to know how to create a Center like HARC, what needs to be done, and why some things work and others don't.

Creating a Center for the Performing Sciences requires enormous commitment, investment, patience, and even luck. The location, resources, and culture of the community all play significant roles, and what succeeds in one place may fail in another. A Center for the Performing Sciences is as much about personal chemistry and emotional commitment as it is about vision and strategy. It also demands a rare kind of individual, people I call the "two percenters." I'll talk about the two percenters later.

A NEW DESIGN

In 1970, two years after taking a leave from the semiconductor R&D labs at Texas Instruments (TI), I completed my doctoral degree at Texas A&M University. I then worked at the university as an assistant professor of electrical engineering while helping the university develop the Institute for Solid State Electronics. This was a heady time of growth in R&D, and government support for research and development was strong. It was also a down period for the micro-electronics industry, and TI was focusing on new automated processes for manufacturing integrated circuits, an area it had invested in heavily.

My return to the R&D labs offered significant opportunities for me because of the investments TI had made in programs I had developed there earlier. I had also just received the first government R&D contract for the electrical engineering department at Texas A&M. So I was faced with the interesting dilemma of either returning to TI or remaining at Texas A&M as a professor, continuing with the development of the Institute for Solid State Electronics, and consulting for TI. Because of my interest in finding ways for the academic and industrial sectors to work together, and my belief that this is more effectively done in the academic setting, I decided to remain at Texas A&M.

This was a wise decision. It involved me in the challenges of bringing an academic institution and a microelectronics company together, even when good personal relationships were already in place. Texas A&M wanted a world-class research center in the emerging micro-electronics field. So the university needed a strong faculty, knowledgeable and committed to the semiconductor and microelectronics world. And Texas Instruments, during a depressed economic period, wanted to have a working relationship with scientists and engineers the company could not justify employing on a full-time basis.

This was during the early days of the space program. I had received a contract from the Marshall Space Flight Center to explore the possible advantages of processing semiconductor devices in the thermal, gravity, and vacuum conditions existing in space. So I was able to continue working with industry to help develop the government's space program, pursue my own curiosity-driven research, and do all that in the academic environment of Texas A&M University.

IMPROVE? OR TRANSFORM?

This work proceeded rather well over the next five years. The capabilities of our Institute for Solid State Electronics steadily improved, and led to the next opportunity for industry, academic, and government collaboration.

During the "energy crisis," Americans were enduring long lines at gas stations, and oil prices of $100 a barrel were predicted. So I wasn't surprised when I got a call from Jack Kilby, the director of the semiconductor R&D lab when I left Texas Instruments, and the inventor of the integrated circuit and the hand-held calculator.

Jack Kilby stands some 6 feet 8 inches. He is a quiet, unassuming Kansas farm boy who is a great photographer, family man, and grandfather, is exceptionally well read, and is keenly interested in many topics. He is also a man of action.

He wanted me to work with him to develop what we hoped would be a new way to harness solar energy. We envisioned an economical alternative to electricity for the average household. We started a university, industry, and government collaboration for developing a spherical solar cell system that could be a competitive energy source for residential use.

Our project was based on finding a better way to capture the sun's energy to produce electricity, which is what a solar cell does. Of course, we had known about solar cells for some time. The trick was to improve the efficiency and find a reasonable storage method. Jack believed he had better ideas, and invited another TI colleague, Jay Lathrop, to join us in creating this new technology. We did the work in my labs at A&M's Institute for Solid State Electronics. Jack used

funding from TI, which had the right of first refusal for licensing under its agreement.

Most solar cells are flat and when the light energy from the sun hits the cell's silicon it causes a "free" electron to be generated. That electron has to travel across a junction, much like a soldier behind enemy lines trying to get through to his unit. This "no-man's region" is called the "forbidden zone," and if the electron manages to cross it, then it can be put to work toasting bread, brewing coffee, or powering a computer.

The breakthrough idea that Kilby, Lathrop, and I worked on, and that formed the basis for several patents, was the spherical solar cell. Instead of altering an existing flat cell, we recognized that we needed a new mechanism that would improve the probability that an electron will make it across the forbidden zone.

The conclusion that we reached about improving a photovoltaic device is similar to my conclusion about improving technology transfer. A gap must be transcended. Modifying existing structures is not the answer. The new approach must nurture the bringing together of talent and technology from university, industry, and government, and it must reward successful collaboration. This new design would not be limited to the technical side of managing talent and technology, but would also include marketing, management, and financing.

Universities have not operated under this model, and it is debatable whether they should. This is especially true for state universities constrained by the politics of spending the public's money as well as with trudging through layers of bureaucracy.

A new design is needed because the world is changing. Society has progressed from an agrarian-based economy, to an Industrial Revolution, to a knowledge-based economy where there is the individual, and intellect. Those companies that know how to use both will succeed. Today, and in the future, individuals will change jobs frequently and will constantly need to update and upgrade their skills. How the knowledge-based economy operates, where the internet is the vehicle and the Center for the Performing Sciences can make any city a port, is changing the way we think, compete, and work.

We are moving in an economic direction where there are no longer jobs, just work. Many different companies across many industries have similar knowledge needs and this knowledge is circulated in new and different ways.

All of this points again to the missing piece, where top talent and technology that can serve multiple needs comes together and solves problems in a collaborative way. What is needed is a place within the community to spin off new companies based on new technologies, to help create new products for existing companies, and to stimulate interest in the value of knowledge as well as its creation. As talent becomes even harder to find, creative mechanisms for sharing it will have great value.

Centers for the Performing Sciences can work

- With industry to provide both talent and technology
- With government to support economic development
- With universities to create technology and further train and provide experience for their faculty and students in the use of technology

- With the community to improve the economy and raise the level of awareness of the importance of technology in a knowledge-based economy

A NEW LOOK AT THREE CULTURES

At a time when we are challenged to respond creatively to increasing global competitiveness, two crucial questions arise:

1. How do we bring technologies developed by government and university laboratories to the attention of industry?
2. How do we bring the needs of the marketplace to the attention of academia and government, particularly when individuals in these sectors have long ignored commercial objectives or have denied their validity?

A third, and perhaps larger issue is whether we should even try to change established cultures of these three sectors. If such a change occurred, would we run the risk of losing the unique ability of each sector to perform its established and proven function in society? Even if this were acceptable, is there time to change a reluctant culture given the rapidly changing and competitive world we live in? The questions become, Do we try to change existing cultures, or do we create a new institution with a new, and different, culture? Or, can a new dimension/responsibility be added to an existing institution?

Where do we turn for answers in a knowledge-driven era? Instinctively we have turned to our universities and said, "Grow some intellectual products! Let's get to work creating jobs and wealth so we can improve the quality of life for our citizens."

That's where we discover the forbidden zone. The cultural gap between academic institutions and the economic marketplace is very wide. Like the junction in a solar cell, this forbidden zone makes it very difficult for marketable ideas to find their way out of the university laboratories. The approach to solving this problem must be like Kilby's in tapping solar energy–a departure from the norm; a new idea.

The question becomes, Do we redesign the system, or do we design a new system where intellectual-based products can find their way out of a zone where they exist in abundance, but where they have not been able to move into products needed by society?

After wrestling with this technology transfer problem from a university perspective, I finally concluded that we can't just redesign the system. We have to design a new system–the missing piece. We have to come up with a whole new structure.

My learning curve about this cultural forbidden zone began with my efforts to transfer the photovoltaic technology to Texas Instruments. I got Texas A&M to make an exception to the rules at that time and grant proprietary rights to TI, but this was not done easily. The agreement created stress among my colleagues even at a practical institution like Texas A&M that was already working well as a

land grant, sea grant, and space grant institution. The concept of being an "intellectual product" grant institution had not been considered.

In the 1970s, when Stanford Research Institute was spawning Silicon Valley and North Carolina was building the Research Triangle, not one institution in the State of Texas had a policy that allowed a private company to own or license the intellectual property that resulted from its sponsored research. Even today, profit is a controversial issue on most university campuses. This university culture widens the forbidden zone, preventing technologies from moving into the marketplace and becoming profitable products serving society.

Why does one pursue knowledge? In the university community, knowledge is an end, not a means toward some other purpose. Knowledge itself is the objective. Public universities have the additional responsibility to tax payers. They support the university and should therefore share in the research results. The problem with this idea is that it doesn't recognize the added engineering, financial, and management investment needed to get the research results into products and to bring the new products to the market successfully.

Giving the results of university research to the public actually prevents the additional investment required to convert solid technology into marketable products. If any university, community, state, or nation really wants the people to benefit from state-sponsored research, then they had better find private-sector partners who know the difference between a wonderful piece of technology and a marketable product. In

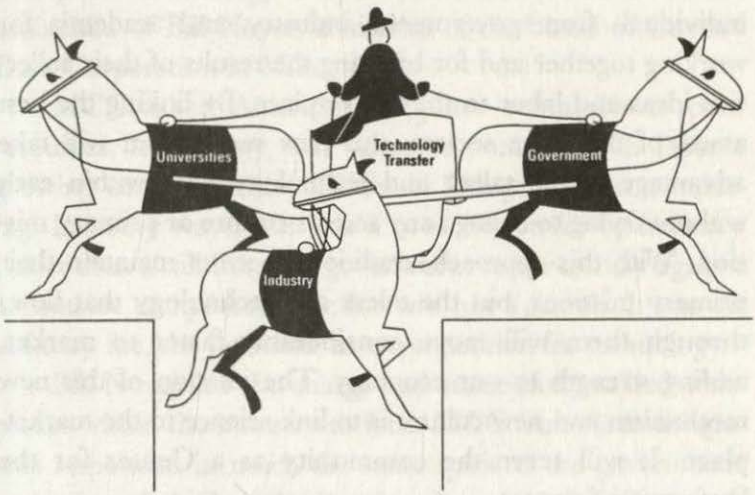

Figure 1 Separate Cultures

addition, those partners must understand the methods of technology transfer and the need for collaboration.

But the conditions for creating such a culture are quite unique, and vary with local circumstances. Instead of trying to change the culture of universities, governments, and companies to embody this new culture, I believe we need to develop a new mechanism to fuel the technology engine of our economy. This mechanism must draw on the knowledge, assets, and special skills of people from each sector; all dedicated to the purpose of transforming raw science into finished products more responsively and more cost effectively than ever before. Collaboration and communication will be its way of working.

This mechanism will create a new culture that rewards individuals from government, industry, and academia for working together and for bringing the results of their collective ideas and labor to the marketplace. By linking the best assets of the three sectors, this new mechanism will take advantage of the talent and technology base within each without trying to change any sectors culture or primary mission. With this approach, traditional sectors maintain their primary missions, but the talent and technology that flows through them will move considerably faster to market, adding strength to our economy. The mission of this new mechanism and new culture is to link science to the marketplace. It will serve the community as a Center for the Performing Sciences.

WHATEVER IT TAKES

In 1982, Austin, Texas, was known mostly as a country music haven, as a college football town, and also as the state capitol. Ross Perot was best known as the Texas billionaire who created EDS and rescued his employees from Iran.

MCC

I was directing the Texas Engineering Experiment Station at Texas A&M when Texas joined in the nationwide scramble to attract the first American-based, private-sector initiative to battle the growing Japanese competitive challenge in the computer industry. The U.S. electronics/computer community had decided that it needed the Microelectronics and

Computer Technology Corporation (MCC). MCC was the brainchild of Bill Noyce, chairman of the board of Control Data Corporation in Minneapolis.

MCC asked American computer companies to pool resources, technology, and talent to compete with Japan's growing competitive capabilities in fifth-generation computing. In many ways, this was a proactive strike by industry rather than a call from the government sector to rally against an outside competitor. The foe was not a nation. It was an industry foe, the Japanese, in a competition for technology.

Bill Noyce led the charge and successfully rallied companies within the industry to form MCC. American companies responded in much the same spirit as the government had responded when the Russians launched their first satellite, Sputnik, in 1957. The space race began. To save America's national pride, and to protect the country from the threat of a space-borne missile attack, the government launched its own satellite program. Shortly thereafter, Congress passed the National Aeronautics and Space Act of 1958, which established the U.S. space agency and appropriated what eventually totaled hundreds of billions of dollars to support the *Mercury, Viking,* and *Apollo* space projects. The United States succeeded when on July 20, 1969, astronaut Neil Armstrong became the first man on the moon, planting an American flag on its surface.

MCC is a benchmark of how industries that typically compete can pull together to survive. My point is simply to say to every community and to every individual that the global economy is here. And we are equipped with the most formidable tool to survive and flourish in this economy: the

ability to think. When individuals develop that capability and produce knowledge and collaborate with one another, the community will be strong.

Creating, attracting, and retaining top talent for economic gain should be the goal for every community. How do we organize, attract, and manage this intellectual asset to serve the community as a whole? This, in my judgment, requires offense. It requires a leap of faith. It requires experimentation. It requires taking risks. In a free enterprise, global community there can be no success without risk of failure. Sometimes in the process we "fail forward."

MCC provided an opportunity to learn. The State of Texas decided that it should be the home for MCC. Governor Mark White asked Ross Perot to lead the business group and me to lead the technical group to form a Texas team to recruit MCC to the state.

The atmosphere was charged with expectation on a bright spring morning in 1983 when the MCC Site Selection Committee gathered for a quail and gravy breakfast at the LBJ Library on the University of Texas campus in Austin. The race by this time had been narrowed down to four locations: Austin, Raleigh-Durham, Atlanta, and San Diego. When our group stood before the MCC group to represent Texas, we had made our leap of faith. We said, simply, "MCC isn't something that would be nice to have. This is something we have to have. So whatever it takes to get it done, that's what we're going to do."

There were turf battles to overcome. Many cities in the state wanted MCC. Because of the selection criteria, selection narrowed down to Austin, mainly because of the requirement that a major university be accessible to MCC.

Our proposal would also require Texas A&M and the University of Texas at Austin to work together to provide the electrical engineering and micro-electronics talent needed to assure MCC the technological resources they sought. We also required the cooperation of San Antonio, which had a winning proposal in all respects except for the presence of a major university. And Mayor Henry Cisneros, in good heart, responded by offering the San Antonio plan for Austin to use.

Our proposal required a group of cities and individuals in a state known for rugged individualism and hard-fought, head-to-head competition to pull together to win MCC for our state. I had the privilege of being a member of a small group in the governor's mansion when we began to lay out our strategy, and then headed the technical team in making the presentations to MCC.

Now, more than 15 years after that commitment and Texas' winning bid for MCC, a once-sleepy university town has grown to become one of the high technology capitals of the world. Dell Computer, IBM, Motorola, and many other technology companies have established an enormous presence in the city. How much of that growth resulted from the state's success in attracting MCC? A better question might be, How much of the growth stemmed from the dedication of the leaders of Austin and the State of Texas to create a center for technological innovation and commercialization? What would Austin be without this effort to focus on the needs of Texas?

I contend that Austin's transformation came about as a combination of many factors. But mostly it was attitude. After all, little direct benefit in the way of jobs and economic

stimulus would come from the addition of MCC. But people began to notice Austin and its efforts, and those who paid the greatest attention were the decision makers looking for a place to locate their high technology businesses. They saw a community ready to embrace them, people who understood what they were all about. And when they took a closer look, they discovered a charming Texas hill country city with a high quality of life and a great education system.

So, what led to all of this? Leaders in the State of Texas, and Austin in particular, recognized the need to develop a knowledge-based economy. They knew that this was something they must have.

SSC

The MCC experience helped me see how community leaders can work together to build win-win partnerships. Now I had a road map to go after a still larger prize–the $10 billion Superconducting Super Collider, a facility with the potential for outstanding technological breakthroughs.

The SSC was indeed located in Texas. Again it was an honor to serve as a member of the governor's team that developed the strategy that won the SSC. Even with the later cancellation of the project, I believe that the experience gained will pay large dividends to the state. One of those dividends was to help build the Houston Advanced Research Center, which put together Texas' technical team to compete for the magnet design and write the Texas proposal for the SSC.

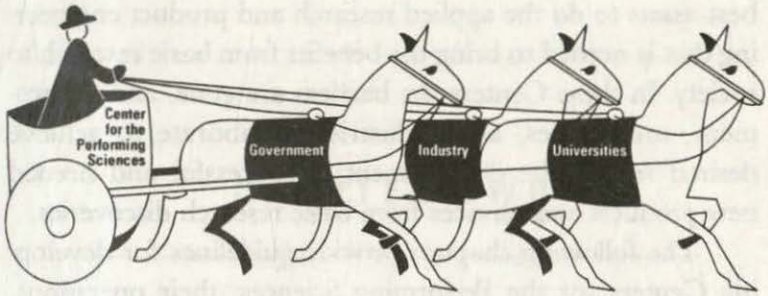

Figure 2 One Culture In Centers for the Performing Sciences

The underlying theme here is cultural change–where people who have been comfortable living one way are now faced with new opportunities. As we all know, however, change never comes without risk.

CHAPTER 1, NOTES AND GUIDELINES

Chapter 1 describes a great opportunity for speeding up the process of developing successful and needed products from the great amount of basic research being done by government and by universities. We can make some progress by working to improve the way the separate cultures of government, universities, and industries collaborate. But we encounter many cultural barriers and constraints in this approach, and progress has been slow.

A new approach is needed. We can keep working to improve what we're doing now. But there is a new, faster, and better way: Centers for the Performing Sciences. In these Centers, government, universities, and industry link their

best assets to do the applied research and product engineering that is needed to bring the benefits from basic research to society. In these Centers the barriers are gone, and government, universities, and industries collaborate to achieve desired results–the development of successful and needed new products and services from basic research discoveries.

The following chapters provide guidelines for developing Centers for the Performing Sciences, their operations, and what they can do.

CHAPTER TWO

A NEW PARADIGM

The world is a vastly different place from the way it was during the post-war 1940s and 50s of my childhood.

THEN

To a small-town boy growing up in the southwestern environment of Irving, Texas, it seemed there was a natural order to things. Life was predictable and change had to do mostly with growing up. In that era and in what I'd call the small community environment, the rule of life was get educated, get a job, work hard, hold the job for life, be punctual, be honest, have integrity, retire, get your gold watch, and play with the grandkids. In most households, the husband worked and the wife was a homemaker who stayed at home and raised the children.

Church was a big part of community life. There was no television, and there certainly weren't any 24-hour news

programs. World news came to us on occasion, but it didn't seem to matter much unless it was a war, which would mean that some of the men in town would have to go and fight. Little League baseball was one of the most exciting things in Irving. The Parent-Teacher Association was important, and for recreation there was summer in the park.

There were a lot of farmers' markets where we could buy locally produced goods that farm families would load in their trucks and drive into town to sell. There were also town meetings where any issue of importance could be discussed by all involved and resolved in a way that generally served the best interests of the community as a whole.

My father's shoe repair business on the town square was about three blocks from our house. I often rode my tricycle or walked with him into town. More specifically, I skipped to keep up because he was a tall man with a long stride. Hence, my nickname, Skip.

Everyone knew everybody. When children rode their bikes, people in their cars would watch out for them. I knew most of the old men who sat on the ledge at the drug store, where I would hang out and listen to talk about the weather and the crops—and if it was an election year, the politics. The pace was slow. What mattered were land, cotton, cattle, oil, and gas.

Unless a new tool or a new piece of technology made life easier or more productive, the process of farming didn't change much. And when something new did come along, the initial response might be skeptical. But if it worked, people

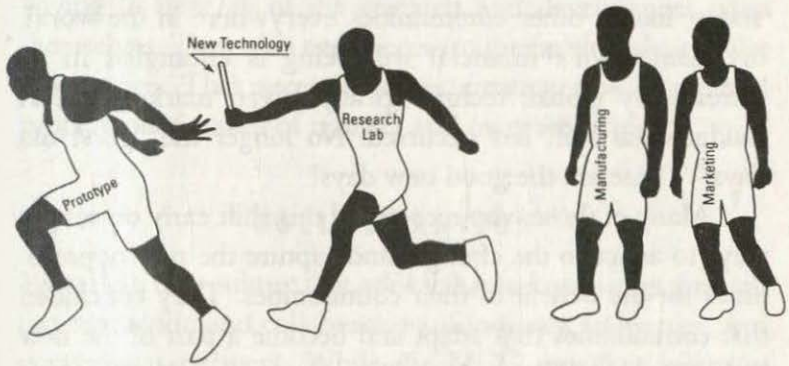

Figure 3 Traditional, Step By Step

embraced it, recognizing the benefits. They didn't think about paradigms.

New technology developed in the laboratory, if it moved at all, moved step by step from the laboratory to prototype, to manufacturing, to the market, each step handing it off to the next.

In the traditional step-by-step procedure there was little coordination and feedback loops were few. So there were multiple opportunities for the technology to be dropped. New technology might not move from the laboratory at all unless interested people in the marketplace learned about it, and pulled it out.

NOW

Today, like in other communities everywhere in the world, my hometown's financial well-being is entangled in an increasingly global, technologically-driven marketplace. A fundamental shift has occurred. No longer the "good old days." These are the good new days!

Many of those who recognized this shift early on sought ways to adapt to the changes and capture the new opportunities for the benefit of their communities. They concluded that communities that adapt and become a part of the new knowledge-based economy will survive and thrive. Yet even those who recognize the changes and the opportunities are often overwhelmed by their scale, and uncertain of what they can do to tap into this new economy.

Their situation is similar to that of leaders a hundred years ago who saw the arrival of the automobile and recognized the onset of a new era. Those communities that created the right environment and incentives for industrial development were the big winners of the 20th century.

In the new economy, communities face tough challenges as they endeavor to tap into the intellectual resources of their universities and to attract other talent that will help the community succeed economically. While most communities turn to their universities, the universities are uncertain about getting involved with economic interests. Their priority is to create new knowledge. Most often they are not skilled or interested in gaining commercial value from that knowledge.

The problem is somewhat different for corporations. In a competitive, global economy, companies need leading-edge technology to compete successfully. Yet few companies can meet this need completely with their own resources. They

need to seek new ways to stay at the cutting edge without having to bear all of the research and development costs themselves. They also need access to the faculty talent of the universities. That access involves creating new intellectual property, and issues of transfer and ownership arise.

COLLABORATION

We need a new culture that adds value to knowledge through the interaction and collaboration of industry, university, and government partners. While the MCC model is relevant, today's competitive environment requires that we go beyond that. We need to create a culture based on collaboration.

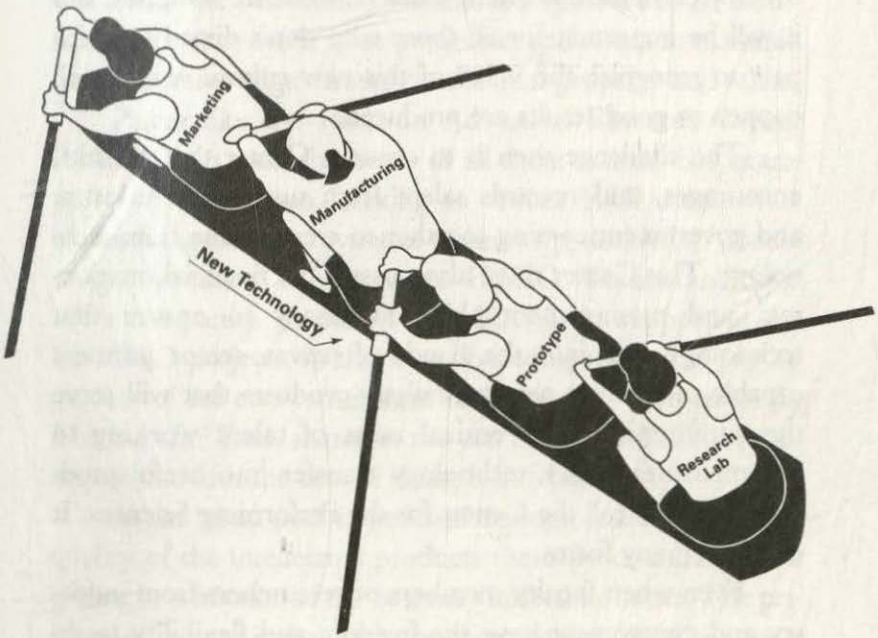

Figure 4 Collaboration

Instead of a step-by-step process for bringing new technology to market we need everyone, at all steps, working together throughout the total process.

With all the players in the same boat, their collaborative actions find, develop, and deliver needed new technology to the marketplace. And the technology is being transferred continuously, not passed off in increments.

About 98 percent of the people in government, industry, and university laboratories may not be able, much less willing, to participate. But the remaining two percent–the "two percenters" described in Chapter 4–will have the energy, desire, and entrepreneurial spirit that is needed. Many already seek new and better ways. If we create an environment where even half of the two percenters can collaborate on projects of mutual interest, this new culture will grow. But it will be important for all those who don't directly participate to recognize the value of this new culture, which will happen as good results are produced.

The challenge then is to create a Center that permits, encourages, and rewards talent from university, industry, and government coming together to create value from technology. This Center must also possess the financial, marketing, and management skills necessary to ensure that technology gets into the hands of private-sector partners capable of creating new-technology products that will serve the community. This critical mass of talent working to accomplish fast-track technology transfer into useful products is what I call the Center for the Performing Sciences. It can take many forms.

Even when faculty members or researchers from industry and government have the freedom and flexibility to do

curiosity-driven research and to teach, they must keep in mind where the money comes from that supports their institution. In a free market, that financial support comes from the hard work of groups of people or even individuals who create a product or service for which others in the market are willing to pay. If there are no profitable companies, there are no jobs. And if there are no jobs, the individuals and companies aren't paying taxes. Profitable industries pay taxes, create jobs, and hire employees who also pay taxes. These tax dollars circle back to support public, academic, and government institutions where those who want to pursue learning and curiosity-driven research are able to do so.

The chain begins with a healthy economy that pays for the university sector as well as for the government sector. A Center for the Performing Sciences is responsive to an industrial sector that needs to be profitable, and needs to maintain its competitive edge through intellectual property and talent.

Places like the Houston Advanced Research Center (HARC), can meet the needs of all three sectors. For example, in 1995 Texaco, seeking to reduce R&D costs while maintaining and improving its technology, decided to donate its geochemistry laboratory to HARC. Texaco and four other companies partnered with HARC in supporting the lab's R&D projects. In this case, five companies each pay 20 percent of the cost rather than each doing its own research. The benefit? Each shares in the use of the intellectual property at one-fifth the cost of doing it independently.

As the talent pool is enriched through collaboration, the quality of the intellectual products these five companies are getting at a fraction of the cost may indeed be better. The primary difference is that each company knows the others have

the same technology. They don't have to compete to create it, but instead compete in its application. The term, "coopertition," has emerged at Texaco. HARC manages the cooperation process, and the free enterprise market takes care of the competition.

A Center for the Performing Sciences can help technology-based industries find new ways to collaborate and reduce the cost of creating technology. A recent collaboration led to the creation of a new company named Genometrix. The Department of Commerce awarded members of a tri-state consortium $9.2 million in matching funds to develop automated DNA chips that could speed the process of DNA sequence analysis. HARC organized the team, which included Baylor College of Medicine, MIT, and HARC as well as private-sector members Beckman Instruments, MicroFab Technologies, Laboratories for Genetic Services, Genosys Biotechnologies, and Triplex Pharmaceutical. The collaboration worked because each member had something unique to contribute:

- The Department of Commerce through its Advanced Technology Program could provide the matching funding.
- MIT and Baylor had the research talent and technology.
- Beckman and the other companies could invest the matching funds, and had the ability to develop and market the products.
- HARC had the experience and mission to bring the parties together in an environment that rewards collaboration.

Genometrix, spun out of HARC, supplies Beckman with neural-network based chips for their instruments. Baylor College of Medicine, MIT, and HARC each own equity in Genometrix and receive research support. Collaboration can work!

CHAPTER 2, NOTES AND GUIDELINES

Chapter 2 develops the idea of Centers for the Performing Sciences and explains how they can help communities thrive in the new knowledge-based global economy by promoting collaboration and wealth generation.

In the past, communities were very localized. Resources, sustenance, knowledge exchange and socialization were all generated in the immediate area. Change happened slowly and in a piecemeal fashion. Now the small town has been swallowed up, literally and figuratively, in the global marketplace. The pace of change and the scope of our lives today is huge. The ability of communities to thrive depends on learning how to adapt to that change and become part of the new knowledge-based economy.

Universities create knowledge and technology that helps us adapt. But university culture is not geared toward creating commercial value from technology. Corporations, on the other hand, are skilled at developing commercial value. But they can't bear all technology R&D costs on their own. And they lack university knowledge-seeking talent.

The solution? Harness the knowledge-seeking abilities of universities, the facilitation resources of governments and NGOs, and the profit-seeking capabilities of corporations in Centers for the Performing Sciences. These Centers can

generate knowledge and its commercial value through collaboration. What is more, corporations can collaborate among themselves to share the cost of technology generation, while still competing in the commercial development of that technology.

A prime example of corporate collaboration can be found here in Texas. Texaco donated its geochemistry lab to the Houston Advanced Research Center (HARC), then partnered with four other companies to provide financial support for the lab's research. Texaco has coined the term "cooperition" to describe how the companies shared the R&D benefits and costs and then competed in its market application. The success of this kind of collaboration rests on the constant allegiance to profitability that corporations bring to knowledge generation. This allegiance results in funding for research and commercial application of the technology generated, to the benefit of the whole community.

CHAPTER 3

UNIVERSITY TRADITION RUNS DEEP

Consider how the Pacific Northwest salmon, which spawn in fresh water, migrate to sea to grow and mature, then return to their natal streams to reproduce. The salmon population is threatened today not by bears converging on streams, but by human population growth and economic development.

The salmon need access to better hatcheries, richer nutrients, and cleaner streams to get them to their next stage of life. The same might be said for the spawning grounds of technologies, our universities. What is missing are the hatcheries that nurture ideas and send them out on their own, ready for a business or a company to develop them for market.

RURAL ROOTS

In a broad sense, the economic eras of Texas are not that different from any other region of the world. Back up far

enough in time and you'll find a Texas where great wealth was related to land ownership, the ranch, or plantation. Raising cattle or cotton were the true sources of wealth in an agrarian economy. The land grant university system, as envisioned during Lincoln's presidency and enacted under the Morrill Act, was not established only to educate the state's sons and daughters. It also was intended to provide farmers and ranchers, who were the backbone of the economy, with information on the latest technologies, and improved strains of seed or cattle.

If new technologies and information were to reach the economic drivers throughout rural communities in Texas, then a new mechanism had to be created at the University to help sell the state's beef and crops. In Texas, as in many other states, this was accomplished through the creation of an agricultural experiment station and an agricultural extension service. In Texas, both were housed within Texas A&M University's College of Agriculture. More than 100 years later, these institutions still serve under virtually the same model.

TRANSITION

In 1914, the Texas Engineering Experiment Station (TEES) was created to help the state deal with the transition from an agrarian-based economy to an industrial-based economy. TEES was set up in the Texas A&M University College of Engineering, and was directed by the dean of that college. Like their counterparts in agriculture, these kinds of organizations, until recently, operated in much the same way as when they were founded.

In 1980, several years after the Institute for Solid State Electronics at Texas A&M was up and running and Jack Kilby had gone back to Dallas with another patent under his belt, I was asked to head the Texas Engineering Experiment Station at Texas A&M. I took the helm of a 66-year-old institution created as a sort of technology-transfer arm of the state some 45 years before the first integrated circuit was developed. My mandate from the A&M Board of Regents was to expand this locally operating institution, which directed the work of 26 research divisions, into a statewide operation that would better serve the larger community. We grew TEES from a centralized $3 million annual research operation to a $30 million annual interdisciplinary operation with outreach locations in North and South Texas.

It was during this period that I learned how wide the cultural "forbidden zone" is within academia as well as between academia and the private sector. I also began to understand how the cultures of our existing institutions kept them from adapting to new economic realities.

Even with its substantial growth, TEES was only slightly better equipped to deal with the changes that were driving the information revolution emerging around us. In 1980, the state's public universities had not yet developed policies for dealing with intellectual property issues.

TECHNOLOGY TRANSFER

I remember well the discussions about intellectual property and technology transfer issues at university executive committee meetings. "Skip," the director of the Texas Agriculture Experiment Station said to me during one of

these discussions, "the way we transfer technology over here in Agriculture is you just call your neighbors and tell them you've got a sack of that new hybrid seed out on the front porch and to come by and get a cupful."

"When we develop a new microchip over at Texas Instruments," I replied, "we sure don't call Motorola and tell them, we've got some new microchips on the porch and they ought to come by and get a cupful." The fundamental view, that a tax-supported public university must share research results equally, would often emerge as we argued about public-private partnerships in technology development and transfer.

"Don't all the citizens pay equally to run this place?" someone once asked me during one of these exchanges.

"Yes. Everybody's taxed and then Texas A&M gets the money from the state."

"Then doesn't everybody own it?"

"Well, yes."

"Then how can we let some one person or company come in here and buy it, since everybody owns it?" Shouldn't we just give our work away to society?"

"Well, no."

Someone has to put a huge amount of money at risk to create a marketable product out of a new technology. We could tax everyone to do that, but if we did we would be applying an economic model that has already failed. And you remember what that system was called!

These issues are still being debated. The roots of university culture run deep and are firmly established. It is difficult for the average citizen to understand the "forbidden

zone." Progress is being made in dealing with the issues, and developing policies for technology transfer to the private sector. The debate about what role our universities should play, however, continues. Time will have to pass before a clear picture emerges, particularly for the publicly supported institutions. I will discuss my recent work at the University of Oklahoma and the State of Oklahoma in a later chapter.

PROFIT IS OKAY

Historically, communities have taken great pride in recognizing, celebrating, and promoting their universities. The university community has reveled in that attention and respect. Today, communities are asking for something back.

Communities are now looking at their universities and expecting them to spawn a Research Triangle Park or a new business incubator. Communities want their needs addressed, and they want the economic value that can be spun out of the human mind. The reality for today's academician is to understand that their efforts must be relevant, not just respected.

The disconnect between my arguments and the traditional thinking inside the higher-education establishment in Texas in the early 1980s was not just academic. It was a reflection of a society still grappling with new ways of thinking as our world shifted into a new economic model. We are still struggling with this transition.

Agriculture was, and remains, an important part of the university curriculum at Texas A&M. During my years as director of TEES, I tried to explain to my colleagues from

the agrarian culture why the university needed to have policies that allowed university research to be privately owned, and the sale of university-developed technology to the private sector. Unlike farming, I explained, there never was cost protection for the crop of semiconductor chips to be "grown" at Texas Instruments. In fact, it simply would never have occurred to anyone in a technology company to ask the government for that kind of help to keep the laboratory running.

There will always be, and probably should be, certain services and/or products in a community that are guaranteed. People need transportation so the community builds and maintains roads, for example. But that has not prevented toll roads from cropping up in a private-sector competitive mode. Some also argue that medical services, utilities, and other services should be provided to all. Governments will undoubtedly continue the debate over which essential services should be provided, regulated, or privatized.

When it doesn't work to control a service, like communications or the airlines, we deregulate them. The deregulated utility industry in the United States is changing a $300 billion a year market. Companies like Enron are emerging that aren't producing gas any more. They are trading gas and kilowatt hours. When we deregulated the communications industry, very competitive industries and companies within industries were created to provide needed services and products.

Everybody has to eat, so shouldn't the government guarantee the farmer a profit since they were taking enormous risks to grow the crops? Our country has to be defended, and the university has a program that trains military people to defend the country. In the early 1980s institutions

like Texas A&M, a land grant university with a strong agricultural school and a strong military program, served the state primarily through government funding. This culture of community service for the good of all is difficult to change in order to support a free-enterprise, competitive marketplace where one must invest a lot of money and may lose it all.

There wasn't a sense that everybody needed to have an integrated circuit, and therefore those who grew them were not guaranteed a profit. Today, that view might be different!

I found myself as a member of the executive committee of a traditional university system arguing that the system needed to have an intellectual property policy to allow just one of those free enterprise companies to make the investment, take the risks, and assume the ownership so they could turn a technology into a profitable product. If successful, society would benefit. It was unrealistic to expect any single company to risk the capital if it didn't have a parallel opportunity to benefit.

The university has to find its way to participate in the technology transfer and innovation process as effectively as it has found a way to participate in supporting the soldiers who defend our nation. The mission is to serve the common good. The challenge is changing the way it is done. Centers for the Performing Sciences can help.

At the core of making the leap of faith that a community must take to play this high-risk game is the need to serve the common good in new and different ways. Public/private partnerships may be the best way.

My argument then was, "Look, let me tell you why Silicon Valley is Silicon Valley–it's simple: Stanford University and the Stanford Research Institute (SRI) are

there. They sell their technology to companies like Hewlett-Packard and to the venture capital community, which then put tens of millions of dollars at risk. The investors may lose. There are no guarantees. But they aren't willing to take the risk unless they can own the upside potential as well. We simply have to sell this technology. And that means we need a user-friendly intellectual property policy."

Texas eventually managed to get these policies in place for its universities during the time Jack Kilby and I served on the governor's Science and Technology Advisory Council. I finally recognized the necessity for new, private institutions created with the specific mission of transferring technology.

CULTURE AND MISSION

It was probably obvious, but what I failed to recognize was that the university has a culture that is resistant to this new role. It goes beyond the university's basic mission of teaching, research, and service. It surpasses the individual's desire to create knowledge as an end, without having to think about its use.

The mission of the university first and foremost is to educate. It attracts bright people who are motivated to go where their minds lead them, not where the market leads them. It gets back to the old question of "technology push versus market pull." The faculty of a university can't be pushed or pulled anywhere by the marketplace, or for that matter by the university president. A valid question here is, Do we really want that to change?

I can't predict how well the traditional university will do in our new knowledge-based economy. I can say that the

need to find effective methods for distance learning, to reduce the costs of operations, and to compete for fewer students will force institutions to change. New opportunities for the private sector to engage in teaching and training will emerge. Motivated by industry's need for skilled workers, individuals and companies will find ways to teach skills more effectively and efficiently. While the classical focus on teaching our sons and daughters to think should never change, the ways we go about teaching will change.

The greatest threat to the future of the academic institution comes from faculties who feel that the institution is there to serve them as opposed to serving the students and the community. In the final analysis, serving the community and participating in a healthy economy must be the mission for all institutions. When that happens, everyone benefits. For the university, it is a privilege to create learned individuals capable of thinking, and to graduate them into a society that will value their intellect and abilities.

NEED FOR A NEW INSTITUTION

I believe that the traditions of universities will not permit them to change fast enough to help industry take full advantage of the knowledge needed in our competitive economy.

Universities should stay focused on producing thinking people, and conducting R&D to keep the faculty at the cutting edge of their disciplines. This is particularly true for publicly funded universities. What is also needed is a new mechanism that brings the two percenters from academia, industry, and government together to push at the forefront of knowledge creation and knowledge utilization to discover, define, and distribute new intellectual property.

Consider the motivated and intelligent person who chooses to become a college professor, compared with a classmate who decides to risk all on an entrepreneurial start-up. Those who pursue a life in higher education typically are driven first by their need to contribute to the community. They give up the long-term financial potential their classmates pursue and are motivated instead by the long-term stability and security of tenure, and the pursuit of ideas. With this security they are able to enjoy the intellectual freedom their profession offers.

If the development of intellectual properties in science and technology are needed to stimulate economic health, a community should be developing new tools to perform this work. It shouldn't be forcing an unwanted role on a faculty that is not motivated by market needs. Not only is the university culture too distant from the task at hand, taking on this task runs the risk of de-focusing the university from its primary mission of teaching, research, and service.

If a high school senior comes to the university to learn about admissions and academic programs, while another comes desiring to develop a technology-based idea, who deserves the university's greatest attention? Is it reasonable to expect the faculty to respond well to both requests? Are they organized to do both?

Perhaps it is better to create institutions that are specific to the task–Centers for the Performing Sciences. Such Centers, with their unique mission, will attract the "two percenters" from among faculty members who are willing and able to play the technology transfer game.

CHAPTER 3, NOTES AND GUIDELINES

There are cultural obstacles in academics to the sale of technology to private industry. This culture developed in land grant universities with their mission of social service based on agrarian values.

There are two sides to this intellectual property rights debate:

1. Academic research at public universities that leads to technological progress is funded by everyone through their taxes. Therefore, shouldn't results of research be free gifts back to society as a whole, rather than to one or two corporations?

2. Private corporations make a big investment in development costs and take financial risks to create a marketable product out of a new technology. Shouldn't they be rewarded for this work with intellectual property rights and a greater potential for profit, since this wealth generation will benefit all of society?

The question is, Do we really want to overcome these cultural differences between business and academia? The primary mission of universities is teaching, research, and service. Academics have a responsibility to the greater society to do work that is relevant to society. Trying to change the culture into a profit-driven one may compromise the university's true mission. How can cultural differences in academic and for-profit cultures be overcome to foster the technology transfer and innovation process? One way is through facilitation by

Centers for the Performing Sciences–new private institutions created with the specific mission of transferring technology from the academic world to the corporate world.

CHAPTER FOUR

HOW CENTERS FOR THE PERFORMING SCIENCES START UP

I've talked a lot about why a "community" must recognize the need for a new knowledge-based, economic development center. But usually it's only a handful of people who drive themselves and the community toward this vision. I've been privileged to watch some of these leaders in action. Even though every situation is unique, when these leaders decide to meet the need, the processes they follow have much in common.

One common element seems to be, when they begin, none of these leaders has a clear idea of exactly how to accomplish their vision. It will be a process of discovery. However, without fail, they sense the need for a Center that will tap into the emerging knowledge-based economy. They explore, seek, and probe to figure out what the Center should look like and how it's going to work. This open-minded

pursuit finds solutions based on the unique natures of these leaders and the realities of their communities. In fact, this discovery process often extends well beyond the creation of a new Center. Indeed, Centers for the Performing Sciences must be evolutionary if they are to survive.

THE HARC IDEA

My earliest experiences with this kind of leadership came shortly after I arrived at the Houston Advanced Research Center in 1985. The visionary and financial force behind HARC was George Mitchell, a Galveston native and son of a Greek immigrant. George started a company with a used drilling rig, discovered a huge natural gas reservoir in North Texas, and became the founder of Mitchell Energy. He was passionate about sustainable development and was putting his ideas into practice with his company's development of The Woodlands, a 25,000-acre planned community in the pine forests north of Houston.

In 1974, George and his wife Cynthia assembled a group of business and academic leaders who shared a common concern about global issues. Together, they forged plans for a multi-year program to seek solutions. The resulting Woodlands Conference Series launched the following year brought together hundreds of the brightest minds in business, politics, and education.

THE WOODLANDS CONFERENCES

The Woodlands conferences and international essay competitions laid the groundwork for what was to become

the Center for Global Studies, the policy research division of HARC. Today, this Center focuses on global environmental issues, sustainable development, and the social and policy implications of science and technology.

As the conferences grew in stature, many of the state's major universities stepped in to provide leadership. George saw the synergism created when business people, government representatives, and academicians worked together to produce something greater than the parts. His interest grew in doing more.

"I believe if we could get the state's major research universities to work together on projects they couldn't do individually," George said, "and if their top talent could meet with the government and private sector in a collaborative atmosphere, it would help get research into the marketplace more quickly." He also believed that The Woodlands might be an ideal site for a university consortium and a research center.

THE HARC IDEA DEVELOPS

George began working with Texas A&M University, Rice University, and the University of Houston to establish the Houston Area Research Planning Committee. In early 1980, the group awarded a contract to Arthur D. Little for a feasibility study. The study looked at all of the major research institutions that had spawned knowledge industries, such as Silicon Valley near Stanford, and Route 128 near MIT.

The one that seemed most relevant was North Carolina's Research Triangle, a planned research park created in 1959 by leaders from business and academia to attract companies doing world-class research and development in

scientific areas. The Park's greatest attraction was Research Triangle Institute (RTI), where interactive research is carried out by talent from Duke University, North Carolina State University, and the University of North Carolina at Chapel Hill. The planning committee's report in December, 1980, concluded that The Woodlands would be a viable location to establish a collaborative research center for basic, applied, and policy research to be funded by contracts, grants, and gifts.

After more than a year of additional planning, Mitchell approached the boards of Rice, Texas A&M, and the University of Houston, inviting them to join in a collaborative research center that would pool the capabilities of those institutions. On September 7, 1982, a partially assembled board of directors of what was then called the Houston Area Research Center met at the Houston Club Building in downtown Houston. They agreed to develop a mission statement and an organizational charter and to create an executive committee.

The board wanted HARC to become a catalyst for new research that any one of the universities alone could not undertake. They set out to create a model that would integrate the diverse cultures of private industry and institutions of higher education.

Much was accomplished by the time HARC's board met in April, 1983, at the headquarters of Mitchell Energy and Development in The Woodlands. University of Texas Chancellor Don Walker telephoned Mitchell during the meeting to express interest in joining the new consortium.

THE HARC IDEA WORKS

George viewed HARC as the intellectual hub for what eventually became the Woodlands Research Forest, with many high-tech companies locating there. And, like the Research Triangle Institute in North Carolina, HARC anchored a real estate development.

By 1985, we had projects to pursue. HARC established the Texas Accelerator Center and began work on superconducting magnet designs for application in the Superconducting Super Collider project in Waxahachie, Texas. Another project was to establish a supercomputing center. Although HARC just missed the cut to become an NSF National Center for Excellence in Supercomputing, we decided to pursue a center anyway.

George and I were exploring what HARC would become and how it could work for economic development as we traveled to Minneapolis in the summer of 1985 to visit Control Data Corporation. We spent the morning touring the company's supercomputing division and hearing the story of their liquid nitrogen cooling system. But the highlight of the day came during a casual conversation between George and CDC Chairman Bill Norris.

After we arrived at the CDC board room for lunch, George and Bill stood at the floor-to-ceiling windows that overlooked downtown Minneapolis and the sprawling university and medical complex below. The conversation went something like this: "You guys have really done a good job up here," George said. "Your universities have spun out all

this medical technology and you've got this huge medical complex and all this activity going on here. How did they do that?" Bill turned to George and said, "Hell, they didn't do that. Those guys didn't transfer the technology. We had to go in there and pull it out."

Bill's statement has great significance for anyone hoping to create their own Center for the Performing Sciences. What Bill described was that same "forbidden zone" I had encountered from the academic side. Part of recognizing the need for a new kind of institution is to recognize the limitations of the way things are now.

INVOLVING PARTNERS FOR WIN-WIN OUTCOMES

In HARC, with the collaboration of industry, academia, and government, the "forbidden zone" diminishes and disappears. Technology moves from discovery through development to products and services useful to society. Here are a few examples.

HARC's Geotechnology Research Institute teams with partners in industry and government to develop leading-edge geotechnology for oil and gas exploration and production. Over the past few years, HARC was able to enhance its world-class research and analytical services through the addition of a Geochemistry Laboratory (donated by Texaco) and a Rock Physics Laboratory (donated by Unocal with additional support from ARCO, Exxon, and Texaco). Through research partnerships, energy companies share the benefits of the latest technology and reduce many of the costs and risks involved while helping to keep energy plentiful and affordable for consumers.

HARC, NASA, FEMA, and industry sponsors successfully flew a number of missions across the nation to test the technical feasibility of ALTMS, an Airborne LIDAR Topographic Mapping System sensor that generates high-resolution topographic maps superior to conventional terrain mapping technologies. ALTMS is being commercialized in such fields as flood plain mapping, pipeline monitoring, coastal erosion mapping, mineral exploration, ecosystem characterization, and telecommunications. ALTMS shows that government and industry can effectively collaborate through HARC to help end-users improve flood control and emergency response planning as well as insurance coverage.

In a new application, ALTMS provides a database for "smart cars," allowing cars to anticipate upcoming terrain and adjust power sources to compensate and thus conserve energy.

In the area of accelerating the application of new technology, HARC has developed an Industry Sponsored Consortium to test and evaluate stationary fuel cells. The consortium is made up of a diverse group of companies bringing unique perspectives to the study of the future of stationary fuel cells and the impact of the technology on business and society. Companies include Texaco, Southern Electric, Dana Corporation, Salt River Project, and Walt Disney Imaginary.

As mentioned earlier, some of the same HARC talent that supported the SSC is now applying a portion of that knowledge in a commercial way, meeting new challenges in the electric power market. The $300 billion/year industry is rapidly moving toward increased competition as a result of the Federal Energy Policy Act, which opened the wholesale electric power market. The transition to a wholesale market will undoubtedly require a number of enabling technologies,

and HARC is working to help Houston and Texas stay in the lead as the energy capital. The state's Energy Conservation Office and Public Utility Commission are supporting research projects at HARC to evaluate the feasibility of superconducting magnetic energy storage (SMES). HARC has assembled a consortium of key industry players who are now performing SMES transmission enhancement studies to determine whether SMES units can be used effectively to stabilize the flow of electricity. This will translate to new power companies for Texas and lower utility costs for customers.

In a related area, HARC's Center for Global Studies and the University of Houston published a 64-page *Guide to Electric Power in Texas*. The fact-filled report contains essential background on the electric power system in Texas and objective information for understanding the debates on deregulation of electricity. The publication is available to the public through HARC.

HARC's policy arm, the Center for Global Studies, examines the connections between resource constraints, economic growth, and environmental quality. We published the results of a two-year study identifying the most pressing environmental risks in an eight-county area surrounding and including Houston. Coordinated through HARC and supported by Houston Endowment and other private gifts, the project analyzed and ranked environmental concerns according to their relative risk to human health, ecosystems, and quality of life. The report is designed to help Houston identify and deal with its environmental problems.

On a larger scale, HARC is working with the National Academy of Sciences in the multi-year Global Commons Project to design a template for addressing sustainable development issues of the next five decades, a time when the world's population will double. HARC's role is to involve the private sector in identifying problems and seeking solutions. Several major corporate partners have already endorsed the project and are providing financial support. HARC and Rice University, in partnership with the National Academy of Sciences, sponsored the De Lange–Woodlands Conference, a three-day international colloquium to explore the transition to sustainable development as a first-step in the Global Common Project. The event combined the biennial De Lange Conference of Rice University with The Woodlands Conference series of HARC.

A grant from The Fondren Foundation of Houston made possible the establishment of a Telemedicine Laboratory at HARC. The group's mission is to work with local hospitals, medical schools, and other members of the medical community to identify promising technologies that focus on expanding the delivery systems for medical diagnosis and treatment.

THE TWO PERCENTERS

The first questions to deal with when building a new institution is, Who should be on the team? Do you choose the people first and let them direct the evolution of the programs? Or do you choose the technology and then find the people to fit those particular areas?

SELECTING THE PEOPLE

Some of both approaches may be needed. But, either way, exceptional people, whom I described in Chapter 2 as the "two percenters," must be recruited. These individuals want to do more than their current careers in industry, academia, or government can allow. They are driven and excited by seeing how research can be turned into a product and how that product can be successfully marketed. They are motivated by the process of collaboration.

The challenge, then, is to create a Center that permits, encourages, and rewards talent from universities, industry, and government to come together to create technology and gain value from it. The Center must also have the financial, marketing, and management skills needed to assure that technology gets into the hands of the right people.

Dealing with that first question, if people are chosen to direct the evolution of the Center's program, the Center will need people who are motivated to use their intellect to build the important technologies that can contribute to the economic health of the community. The Center will be seeking relevant scientific excellence. In the second approach, technology areas will be chosen that are critical to the community, and the Center will want to take advantage of market opportunities by developing further capabilities.

For example, HARC is developing superconducting magnets for energy storage to help independent power producers in "wheeling" electricity through interconnected transmission grids. The magnets were first developed for controlling the proton beam in the SSC. Having developed a new technology, people who are excited about their specialty

and who have the technical ability to develop forefront technology can create new applications responding to market needs. Bringing people into the Center who are passionate about their work provides a competitive advantage for the Center, and for the community.

Since the Center's mission is to see that science performs for society, an important need is "cultural matching" in the selection of people. By this I mean that it is important to seek individuals who come from a culture or can easily adapt to a culture where everyone is motivated by and attentive to how the community will benefit from their work. This is different from the "scholarly" approach where the institution seeks individuals motivated to follow their own intellectual pursuits hoping that what's interesting to them can be published. The thought that their work might be put to use by somebody, somewhere, sometime is left to chance. Their motivation is scientific excellence.

BASIC VERSUS APPLIED RESEARCH

The intellectual community has long debated the relative value of "basic" versus "applied" research. We debate the relative value of "R&D" versus "services, testing, and evaluation," intellectual purity versus commercialization.

We miss an enormous opportunity if we don't pay attention to both. If researchers developing a specific product will listen to the research results, they will likely discover new, fundamental knowledge. And if those interested only in pursuing basic knowledge will follow where the research leads, new applications will become apparent and great products will be discovered.

It's amazing what you can hear by just listening to the experiment. No matter what your intent was when you entered the laboratory, the experiment will "scream out" a result most likely never anticipated. Galileo Galilei, the first person to apply the scientific method to nature, commented on this process in his autobiography: "When a person has discovered the truth about something and has established it with great effort, then, on viewing his discoveries more carefully, he often realizes that what he has taken such pains to find might have been perceived with the greatest of ease. For truth has the property that it is not so deeply concealed as many have thought." Galileo was quick to add, "Yet it often happens that we do not see what is quite near at hand and clear."

My own experience doing research both as a physicist and as an engineer has shown me time and again that when I design an experiment to discover a fundamental secret of mother nature, she will unveil a very practical real-world application. Or, seeking an application might find something fundamental. That happened when I was trying to improve the yield of integrated-circuit manufacturing and discovered the conditions for dislocation-creation in silicon.

So the debate of whether to select individuals who do strictly basic versus applied research, or development versus service, testing, or evaluation, wears a little thin. The best team members are those special people who share a common desire to observe what the results are saying and are motivated to follow up by asking how the results can perform for society.

AN EXAMPLE

A historic case occurred on April 6, 1938, when Roy J. Plunkett, a DuPont chemist, accidentally made the first batch of what would later be known as Teflon®. He was experimenting with different gases to create a better coolant. One morning he found that the gases left in a container overnight had escaped and in their place was a white, waxy solid. Plunkett's scientific curiosity led him to think of this not as a "botched experiment" but as an opportunity to investigate a unique material.

He found the new material was impervious to a number of corrosive chemicals, extremely heat-tolerant, and stick-resistant. The discoveries of tetrafluoroethylene resin (FEP) and later polytetrafluoroethylene (PTFE) were purely accidental, and it was another ten years before additional research found a practical application. By asking how the invention could perform for society, Plunkett and many others who followed him at DuPont found numerous applications–products that have benefited society and helped make DuPont one of the world's largest and most diversified chemical companies.

Discovery must be at the core of Centers for the Performing Sciences. Institutions and individuals who are dedicated to making science perform for society are the needed complement to the scientists and engineers in academia, where the traditional goal has been to add to the knowledge base, and to those in government laboratories, where the original purpose was to develop technologies for government use in national service. Today, our federal laboratories are

encouraged to look for commercial applications of their technologies. However, it will be challenging for them to cultivate a culture where intellectual property is protected, licensed, and transferred to the private sector.

RECRUITING TALENT

When creating a Center for the Performing Sciences, it makes sense to recruit talent –the two percenters–from both universities and government laboratories. And it will be important to maintain close relationships with their institutions to develop a culture that can take economic advantage of technology created for other purposes.

Two percenters from industry must also be recruited. They already know how critical innovation is to their company's survival. Individuals working for a particular company in an established industry need to get involved in a Center where, in the multidisciplinary interaction and collaboration, they will find both talent and technology, and market opportunity.

HARC's staff grew by acquiring talent through the restructuring of industry R&D. As mentioned, Texaco donated its geochemistry laboratory to HARC. With the laboratory came all of its intellectual property, equipment, and eight researchers. Formerly working for a single company, these geochemists now make their services available to a consortium of companies that participate in HARC's energy research. Where they once worked in isolation under "strictly proprietary" conditions, they now interact with colleagues from other industries as well as from government and universities.

Society benefits in several ways: Researchers who might have lost their jobs are continuing to work. Texaco gets research at a reduced cost. Other companies, which might have had no in-house research capability, are now sharing in the lab's services.

A Center for the Performing Sciences needs bright people willing to embrace other cultures and to explore other applications to find and develop intellectual products. Galileo had to overcome cultural problems of the forbidden zone when he developed the telescope. He first thought of it as an instrument for gaining maritime and military supremacy, and for demonstrating the principles of optics. It was six months before he considered using it to study the heavens. Why? This forbidden zone was the province of the church.

In our competitive world, the shelf life for technology is decreasing, while the competition is increasing. Centers for the Performing Sciences need creative individuals who seek not only to create technology but who also have the entrepreneurial spirit to put the technology to work for society.

FINANCING

A Center for the Performing Sciences is a place where science emerges from the laboratory to perform for society–where people from industry, academia, and government turn new technology into products that benefit society. Society benefits in two ways:

1. New technology is spun out that improves the quality of life, creates new jobs, and stimulates the economy.

2. If the Center receives a fair equity and/or royalty position and follow-on R&D support, the Center earns revenue for continuing its work.

Visitors often come to HARC hoping to learn a "plug and play" formula that they can take back to their own community. I caution them that there is a period of trial and error that they simply must experience. What works in one place will need to be fine tuned to work for the culture, the economics, the talent pool, and the circumstances somewhere else. Just as there is no formula for establishing a Center, neither is there a "set" dollar amount needed to create and operate such an institution.

START-UP

In my experience in the start-up of HARC, and with private companies, new ventures typically are undercapitalized, and nearly starve to death because they have inadequate funding. Inadequate technology is seldom the problem.

A Center can have excellent top management and the best technology, but if its financial underpinnings are insufficient, nothing is going to happen, at least not for a long time. It takes fuel to fire the engine. A guiding principle for initial funding: Take the long view. The histories of most private research institutes are full of examples of financial struggles in the early years.

One interesting example is described in Weldon B. Gibson's book, *SRI: The Founding Years*. Gibson credits banker and SRI trustee, Charles B. Blyth, with getting SRI through at least three financial crises in its early years. At one

point, in late 1948, the author reports that Blyth almost single-handedly saved the institution from being "liquidated for financial reasons" when he arranged for the institution's refinancing. Often Blyth had to stand up to lending institutions and even other trustees who doubted the institution's ability to support itself in the long term. But he never wavered in his conviction of the institution's promise.

Gibson, a founding member of SRI's research staff, writes that "whatever success SRI may have had in later years–and it has been considerable–is in many respects a testimonial to Blyth's firm support when it was so greatly needed in the late 1940s and 1950s."

Even the perception of being financially stable, particularly in a young institution, is important. For instance, if people believe that the Center will have large cash demands for a period and will be financially stressed, morale can be damaged as well as the Center's ability to attract and retain top talent. Long-term commitment, tied to realistic expectations of performance, is essential for the Center's stability.

The greatest challenge in raising money is building a new constituency. It doesn't just happen. After all, the new Center does not have alumni who earned degrees there, or parishioners who achieved spiritual renewal, or a base of patients it has cured. The Center has talent and economic potential for the community. That's where it begins.

At first it will seem virtually impossible to compete for community support. With time, however, the support will build with those companies that have become healthier and wealthier as a result of the technologies and services the Center has provided. Their loyalty will bring continuing

contract research, technology development partnerships, and philanthropic support.

HARC

Other philanthropic prospects are those rare individuals and foundations who truly understand the Center's present and future value to the community's prosperity. For HARC, oilman and real estate developer George P. Mitchell's continued support has amounted to more than $40 million in operating funds from personal and corporate donations, a 100-acre campus, and a pledge to match other endowment gifts up to $50 million. George's efforts to introduce leaders of business and government to HARC and to win their support have been equally helpful. The reason for this generosity? George responds simply, "HARC has the potential to accomplish much for the benefit of many." HARC is his legacy.

Credibility and reputation are at the heart of successful contracts and research grants. The mechanism by which contracts and grants are won at a Center for the Performing Sciences is not much different from the way it is done at a university or at a company. Key people with established reputations submit clear, well-written proposals that communicate the institution's commitment and ability to do the work. Responding to solicited requests for proposals is always an important avenue for bringing in work and funding. Sending out unsolicited, but tightly targeted, proposals is another avenue. So, build relationships with funding agencies and send solid proposals with creative arguments about society's needs, and involve university, industry, and government talent and institutions.

But how does a young institution gain an established reputation? That takes time, and performance. But one of the strengths of a collaborative institution is that it draws on the credibility of its participants. So a relatively young institution like HARC benefits greatly from its affiliation with well-established institutions such as its founding universities: Rice University, Texas A&M, the University of Houston, and the University of Texas at Austin. Many of HARC's directors also hold appointments at these universities.

For the collaborative relationship to develop and strengthen, the partner must receive value. In HARC's case, this has meant bringing talent together on projects that no one institution could attempt, and successfully conducting classified or proprietary research for industry. Partnering with established agencies, companies, and universities builds reputation.

OTHER CENTERS

An article in *The Economist*, June 8, 1996, describes an innovative way in which the Center of Advanced European Studies and Research is funded. Opened in Bonn, Germany, CAESAR received a one-time infusion of roughly half a billion dollars through federal and state money. A private foundation created by the legislature, CAESAR operates on the interest from this initial investment. Its goal is to recruit bright young scientists and engineers to create new technologies useful to the community, which in time will bring additional income to the institution. This funding method frees CAESAR, and its scientists, from the yearly jockeying for continued government support. I find this an enlightened strategy and approach.

Another creative funding arrangement supports The Netherlands Study Centre for Technology Trends (STT), a nonprofit partnership with public funding from four government departments and equal private funding from the Royal Institution of Engineers in The Netherlands plus over 50 Dutch and Flemish companies and research establishments.

At STT, the majority of the public funding and all private funding is provided annually rather than on a project basis. The Board of the Centre, therefore, is largely independent in its choice of projects. According to Erik van de Linde, STT director, "On one hand, STT would both lose too large a chunk of valuable time if forced to acquire funding on a project basis as well as lose its academic freedom to study trends that stretch farther than market mechanisms (i.e., farther than 10–15 years). On the other hand, the annual character of the funding guarantees that the Center's constituency is continually updated." STT's funding system has been in place since the foundation of the Centre in 1968 and even allows for modest growth of its activities.

Today's politicians seem to be won over easily by programs that create jobs, particularly higher paying jobs for more skilled workers. It is important to make sure that legislators and their constituencies understand the Center's economic scope, especially when a resulting product will not be produced locally. They must understand the benefits of wealth and revenue generation as well as jobs. Value is created when the Center develops and licenses technology that flourishes in the global community. It will still benefit the community by enhancing the Center's reputation and through royalty payments that help fund new projects.

We need to broaden our thinking. There is value to be gained for all players when we seek win-win opportunities that can contribute to the community through the creation of knowledge-based technologies and products.

GENERATING INCOME

As the organization matures and gains experience there will be ample opportunity to negotiate royalties, equity positions, and other income streams during the technology transfer process. Companies that benefit from the development of a technology will most likely want to continue the partnership with the Center through additional contract research. Successful technology transfers also result in enhanced reputation and credibility, which means opportunity to form new alliances with companies that want to enjoy similar benefits.

A sound approach to funding is for both the public sector and private sector to join forces, creating public-private partnerships to secure the finances necessary to create and sustain Centers for the Performing Sciences. It also makes sense to network these Centers together globally. Communities in today's global economy cannot live in isolation. Nor can Centers for the Performing Sciences. They need to be linked and to work together for many reasons, the most obvious being the need for talent and technology. See Appendix A for a listing of Centers for the Performing Sciences, worldwide.

Imagine what could be accomplished if Centers collaborated with partners around the world. Researchers with a problem to solve in America, Asia, or Europe would have the

benefit of their colleagues' ideas at similar Centers throughout the world. Properly coordinated, intellectual-product trading organizations can emerge. I think of these as knowledge brokers. Solutions to problems would be independent of who or where. Extraordinary efficiency is possible through cooperation.

Extracts from Intellectual Property Policies, Appendix C, provides ideas on how a Center can create and share value from its work. With enough good fortune and patience, a long-term goal of becoming self-sufficient is possible.

CHAPTER 4, NOTES AND GUIDELINES

Chapter 4 sets forth a recipe of crucial elements for the successful development of Centers for the Performing Sciences:

- Exceptional people
- Adequate funding
- Commitment to true collaboration on many levels

Centers require exceptional participants, both the visionaries who establish the Center, and the collaborators who carry the Center forward. These people, the "two-per-centers," are among the top two percent of their peers in terms of ability, energy, and motivations. Recruiting of participants should rely on "cultural matching"–individuals who fit well into a culture that emphasizes how the community will benefit from their work.

Centers for the Performing Sciences need adequate financing, to ensure they can weather the funding droughts

of start-up, to attract and keep talented people, and to instill confidence in its supporters that the Center will endure.

Internationally, Centers use various successful funding arrangements. In Germany, one Center received a one-time government endowment so that the Center can live on the interest. In The Netherlands, another Center's annual budget is composed of equal portions of public and private funding. So the Center doesn't have to rely on raising funds on a per project or per corporate relationship/ donation basis.

Finally, a sustainable Center requires commitment to true collaboration on many levels:

1. "Cultural matching" of the people involved.
2. Forming partnerships with agencies outside as well as within the Center's immediate community of beneficiaries. Such partnerships increase the Center's participation in the global economy, and improve the Center's efficiency from the wider sharing of resources and knowledge.
3. Visualizing the contributions of the Center as good for the entire community. What benefits corporations boosts the local economy, attracts jobs, introduces life-improving technology, and therefore benefits everyone.

This understanding of the Center's roles will lead to proper attention to the crucial nature of adequate funding and the endless loop of mutual benefit to the whole society that comes from the Center's efforts.

Finally, just as communities cannot be isolated in today's global economy, so Centers around the world should

collaborate to share technology and resources. (See Appendix A.) Facilitators to the technology transfer process will emerge who will serve as "knowledge brokers" and engage in intellectual product trading.

CHAPTER 5

ADDING VALUE

One of the great pitfalls of Wall Street mentality is that investors expect quick-term results. Rarely in history has a challenging but exciting new opportunity arisen that has been as easy or as swift to achieve as originally expected.

Two hundred years ago, the United States faced a challenging economic need. President Thomas Jefferson put together a team of about 40 men to find a direct water route from St. Louis to the Pacific ocean. He anticipated that the mission could be completed in one to two years and at moderate cost, and that increased trade would result. That campaign, the Lewis and Clark Expedition, encountered many obstacles along the way.

Stephen Ambrose's account of that Expedition in his book, *Undaunted Courage*, tells the historic story. First and foremost, there was no water route. But there were snakes, bears, Indians, biting cold, a number of accidents, the treacherous Rocky Mountains, and severe food shortages. The long-sought Northwest Passage was never found and the

expedition took a great deal longer and cost a great deal more than expected. But the Expedition succeeded in exploring and mapping the West, and opening the way to get value from the Louisiana Purchase, the 828,000 square miles of land west of the Mississippi River that the United States bought from France in 1803.

As communities learn more about the new intellectual frontier, they will better understand how to invest in new expeditions to tap their potential rewards. The adventure will be just as challenging as that of 1804. Threatening barriers will have to be crossed. A team will need to be formed, one that can find the best path to take an idea, generate from it a new technology, nurture the technology into a product, and get that product into the marketplace, competing effectively across the entire globe.

Of course, there will be problems along the way. The team will need committed people with passion, tenacity, and resources. Expectations should be to push the frontier, learn the culture and the cultural differences, and deal successfully with the problems.

THE LONG-TERM VIEW

I cannot restate too often the importance of taking the long-term view. It is simply not realistic to expect a project like this to come into being and start paying dividends in a short time. Instead, we must set reasonable expectations, and define measurable goals when we launch a Center for the Performing Sciences.

As a general rule, I recommend that the community be prepared to invest over a ten-year period in order to provide the basic infrastructure needed, or put together an endowment as in the CAESAR example mentioned in chapter 4. A long-term goal should be to create an institution that will become self-sustaining with a resource base to get it through any tough period ahead.

In a knowledge-based society, the wealth of the community depends on its ability to create knowledge and then, most importantly, to get value from this knowledge. Therefore, performance goals for the Center should include working with other critical sectors of the community–government, industry, and academia–in ways that promote the transfer of intellectual properties to industry so that new products, jobs, and wealth will bring about a higher quality of life.

The difference between creating jobs and creating real wealth for the community comes from knowledge, and knowledge comes from education. Another goal, then, is to educate our community's citizens so they understand and appreciate the process of creating intellectual property and obtaining the benefits.

As the Center matures and becomes more successful in transferring technologies and products into the marketplace, more and more people will become involved. Each experience in transferring a technology to an existing company or in creating a new company for a new technology, becomes a case study. Case studies provide great insight on how to streamline the technology transfer process. They also

provide a ready list of measurable accomplishments, such as number of patents, technology licensing agreements, companies strengthened, new companies created, and jobs created. Studying case examples will also point out areas that need improvement, such as capital availability, intellectual property law, incubators, and mentors.

It is not enough to amass the talent, build the research facilities, and develop the programs. To win broad-based support, sponsors must constantly promote the importance of the Center, and involve the community in its programs. Grants makers, politicians, community leaders, corporate managers, and average citizens, all must well understand the role that this new Center, designed to shape and drive the future, will play in a knowledge-based economy.

As companies in the community and beyond deal with rapidly changing technologies, erratic marketplaces, and demanding directors and stockholders, everyone begins to appreciate an organization that has as its primary mission keeping pace with changing technology. It will be important to reach out to as broad a cross-section of the community as possible to communicate the value of the Center. Even after the Center has the resources in hand, there will be a continuing need for this communication.

RULES OF ENGAGEMENT

People from all over the world have visited HARC. They come seeking ways to attain a higher quality of life for their communities. They share a common curiosity and desire to tap into their communities' resources, and they face similar

problems. The wealth of any community is no longer tied to natural resources or the industrial base but to how well its leadership is able to leverage knowledge.

We have shared with our visitors some of the concepts, philosophies, and ideas, both original and borrowed, used to establish HARC. Other institutions have used different approaches that have also worked well.

Here are important themes common to HARC and other successful Centers:

- Private is better than public.
- Public/private partnerships are the most viable. The private sector is much better at speaking the language of competition, product development, and marketing, while public institutions have far greater political acumen. The CAESAR example from Chapter 4, shows a clever way to make use of public funds for creating a private foundation. The benefit? CAESAR has a permanent income stream and is insulated from changing political whims.
- The Center must connect to society's needs.
- The Center's projects must respond to a changing marketplace.
- The Center must form collaborative ties with universities, industry, and government. The reality is that each of these sectors needs to become keenly attuned to the commercial value of knowledge, and the need for education to develop future talent.

BRAND NEW STATE

Oklahoma is a smaller and younger state than Texas. But it has been a giant on the global energy stage for many years. Today, like most of its peers, the state is struggling to find an identity in the new economy. The great irony is that many of the captains of major corporations, including technology companies, are sons and daughters of the Sooner state. Mike Maples, for one.

Born and raised in Holdenville, Oklahoma, Mike received his bachelor's degree in electrical engineering from the University of Oklahoma. His 33-year career in the computer industry began with 23 years at IBM, in the end as head of software strategies and business evaluation. He then joined Microsoft where he became executive vice president of the Worldwide Products Group and member of the Office of the President, responsible for all product development and product marketing activities.

Like Maples, many high-contribution achievers have their roots in Oklahoma. That's why in 1998, Governor Frank Keating and University of Oklahoma president David Boren approached me about bringing my experience north to help create a dynamic technology culture in the state. They wanted a culture that would create a new breed of entrepreneurs, retain the best and brightest in the state, and, hopefully, lure some of the state's former residents home. The opportunity intrigued me, not just because of Frank and David's commitment and salesmanship, but because I was able to see first-hand brilliant minds hard at work in the university research labs, and potential startup firms creating

cutting-edge technology that will revolutionize business and create new industries.

After accepting the roles of University Vice President for Technology Development and Dean of the College of Engineering at OU and the Secretary of Science and Technology on the Governor's cabinet, I had my first mission: to help ensure passage of State Bills 680 and 681 to encourage technology transfer. The bills passed, with overwhelming support, and now millions of dollars in royalties and numerous patents later, Oklahoma has started on its way to creating this innovative environment.

As I stated earlier, many of the greatest inventions come when you are working to find another solution. This time the "inventor" was my lovely wife Biddie. After hearing one of my talks to a local chamber of commerce, she said in a moment of simple brilliance, "You should be able to find a way to create a thriving technology economy statewide, not just in Oklahoma City and Tulsa." She was right. It was time to take my own advice and see how to take the Center for Performing Sciences concept and link it together from border to border. Best of all, we didn't have to look far to see that the resources were there. We just needed a plan that could get us to success quickly.

Working closely with my colleagues Dr. Jeff Harwell, my right-hand man at the College of Engineering, Dr. John Antonio, director of the school of computer science at OU, and Dr. Karl Reid, Dean of the College of Engineering at Oklahoma State University, we realized Oklahoma had in hand (as many states do) the key ingredients for a low-cost, fast-track, distributed economic development plan focused on software startups.

We knew that half of all new companies today are computer software start-ups. Software start-ups differ from other types of start-ups in that they require less up-front capital and less space, and are especially dependent on access to high-bandwidth telecommunications. Oklahoma has space for software start-ups in its distributed system of higher education. It owns the heart of a high-bandwidth telecommunications network in OneNet. In addition, State Bills 680 and 681 empower Oklahoma's colleges and universities to use these resources to benefit the state economy.

This centralized, statewide virtual incubator will be connected by a state-of-the-art update of OneNet, and can support Oklahoma's own young entrepreneurs on all of its higher-education campuses. The statewide effort will provide the infrastructure necessary to identify and retain these young entrepreneurs in Oklahoma's higher-education campuses, and to maximize their probability of success.

In addition, we have the potential of a steady supply of entrepreneurs in the engineering and computer science graduates of Oklahoma University and Oklahoma State University. Presently, however, there is no special effort either to retain these graduates in Oklahoma or to develop their entrepreneurial talents. Our program leverages Oklahoma's capital investment to identify, nurture, and retain Oklahoma talent and technology and put it to work in the marketplace by fostering software start-ups on our higher-education campuses.

It's an exciting time to see the concept of Centers for Performing Sciences take root in another place. As I've noted several times, creating such Centers is a discovery process.

There will be many obstacles along the way. But what is important is the passion to embrace this new pioneering spirit. The passion is contagious. When people hear the story over and over, it's hard for them not to jump on board and help make a Center for the Performing Sciences a success in their community.

CONCLUSION

Many are asking whether their communities are ready to play this game. Can they find the support required to have a real chance at success? My response is simple. "This is not something that would be *nice* to do, it is something that *must* be done." The difference between creating jobs and creating wealth is knowledge. Knowledge is the key. In order to gain competitive advantage in a changing global economy, we need to take advantage of our community's intellectual resources, its human capital.

As we begin the process of creating Centers that specialize in technology transfer, we must rededicate ourselves to the loftier goals of education itself. When we can make education a lifelong process, communities will have the ability to improve the quality of life. Success will depend on our capacity to think creatively and to find technology-based solutions to help our already stressed planet accommodate a population that is expected to almost double in size in the next fifty years.

Imagine the technological challenges we will encounter as the population grows from today's 6 billion people to the anticipated 11 billion by the year 2050. What will it take to

feed, house, and employ these numbers of people? How can we reduce the income disparities between rich and poor nations? How can we achieve sustained growth that will not further deplete our natural resources or threaten our environment? For the problems we will encounter in the 21st century, I firmly believe we will find solutions in science and technology, in education, in cultural understanding, and in reaching out to all people who might be concerned. Solutions will require collaboration and communication.

Change *is* our friend. Let us celebrate the opportunity to be pioneers again, and cross the knowledge frontier. It is a frontier with risk and hidden dangers. Yet it is one filled with promise. Our willingness to push into this frontier, to take risks, to meet unknown and unforeseen challenges, and to fully invest in our intellectual resources–this will determine how well we meet and help shape the future. Communities that embrace and support knowledge seekers working in a Center for the Performing Sciences are the ones that will succeed in a knowledge-based economy.

CHAPTER 5, NOTES AND GUIDELINES

The global knowledge economy is a new frontier, and we must explore it. This chapter stresses the importance of taking the long-term view when it comes to investing in knowledge/technology research. Centers must help their communities understand "the new intellectual frontier," and the need for up-front investment to investigate and tap its potential rewards.

How will Centers for the Performing Sciences convince their communities of the importance of their role? As they reap the benefits of their initial investment on a case-by-case basis, the evidence in its favor will mount, and communities will see the value of the technology transfer process, and how to streamline it.

The following "Rules of Engagement," based on experience in establishing The Houston Advanced Research Center, may be helpful in establishing other Centers. But there is no "right" way. Other "rules" have worked for other Centers.

1. Private is better than public.
2. Public/private partnerships are the most viable, because they combine expertise in market competition and in political acumen.
3. The Center must connect to society's needs.
4. The Center must respond to a changing marketplace.
5. The Center must represent a collaboration between academia, industry and government.

SUGGESTED READING

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Morgan, Jr., G. T. and J. O. King. *The Woodlands: New Community Development, 1964-1983.* College Station, TX: Texas A&M University Press, 1987.

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APPENDIX A

A LISTING OF CENTERS FOR THE PERFORMING SCIENCES

BusinessLab
Campus 3
Aberdeen Science and Technology Park
Aberdeen, Scotland

The economic and social challenges facing our companies, our communities, and our nations at the beginning of the 21st century are daunting. Many leaders believe their organizations are simply not equipped to address, or even consider, these challenges in isolation. They recognize that a radical approach is required if they are to survive and prosper in the new millennium.

In response to these challenges, BusinessLab was founded by a small group of management, communication, and technology experts. The vision? To provide a creative, collaborative environment in which business, government, and academic leaders can develop an understanding of

the network economy; identify, explore, and test strategic options; and formulate technology-based solutions for their organizations. In short, a business-laboratory for the 21st century.

Within the BusinessLab environment clients have direct access to a diverse range of strategic, communications, and technology skills and to a mix of processes and models designed to facilitate radical thinking in technology-enabled competitiveness. BusinessLab operates from a number of international locations including Scotland and Jersey.

Telephone: +44 1224 332222
Fax: +44 1224 332229
email: grae@businesslab.co.uk
Web: www.businesslab.co.uk

Center of Advanced European Studies and Research (CAESAR)
Friedensplatz 16
53111 Bonn
Germany

When Germany moved its parliament and government functions from Bonn to Berlin, the Berlin/Bonn law of April 26, 1994, was enacted to provide compensatory measures for Bonn. The law identifies four fields of action, the first one being the development of Bonn into a center of science.

Under the terms of the compensation agreement of June 29, 1994, the Federal Government committed itself to pay a total amount of 1.4 billion euro to the Bonn region for science, research, technology, and education. The most important single measure was the establishment of CAESAR, which received a total capital endowment of 375 million euro.

CAESAR is a new type of research center that attracts scientific and economic activities and creates jobs. On signing the Foundation Statutes on July 11, 1995, the two donors, the Federal Government and the state of North Rhine-Westphalia, and also the Federal City of Bonn confirmed their intent to support the construction and operation of CAESAR to the best of their abilities.

The scientific community also largely agreed to the idea of such a research center. The opportunities opened up by this compensatory measure were considered a "windfall for German science," a chance to create something qualitatively new as compared with existing research structures, a Center "indispensable to the future development of science and technology in modern Europe."

Phone: +49 (0) 228/96 56-0
Fax: +49 (0) 228/96 56-111
e-mail: office@caesar.de
Web: www.caesar.de

Environmental Research Institute of Michigan (ERIM)
3600 Green Court, Suite 550
Ann Arbor, Michigan 48105

ERIM is a not-for-profit organization dedicated to the discovery, development, and application of scientific knowledge for the benefit of society throughout the world.

ERIM serves as an integrating force bringing together unique capabilities from academia, government, and industry to develop and apply advanced information, knowledge generation, and complexity management technologies to society's problems and needs.

Core activities include

1. Assisting commerce and industry with research, development, and deployment of customer-supplier network design, software agent technologies, and complexity management to reduce time-to-market and product cost.
2. Serving business and government with the research, development, and deployment of advanced information and Geographic Information Systems (GIS) technologies to enable the sustainability, security, and stewardship of natural resources and other life-supporting systems.
3. Conducting research and development to speed the process by which new technologies and ideas are put to valuable use in the automotive industry.

4. Developing and providing learning strategies for individuals and organizations that are augmented by information and collaboration technologies.

Telephone: (734) 623-2500
Fax: (734) 623-2501
Web: www.erim.org

Georgia Tech Research Institute (GTRI)
Georgia Institute of Technology
Centennial Research Building
Atlanta, Georgia 30332

Over the last several decades, the Georgia Tech Research Institute (GTRI) has developed extensive measurement facilities to support high-quality research in all aspects of electromagnetics, from purely theoretical analysis through advanced applications in phased array radar systems. GTRI has been a national leader in the development of mechanically and electronically scanned antennas, near-field measurement techniques, millimeter wave technology, and threat radar systems.

These capabilities have been greatly enhanced by the construction of the Electromagnetic Test Facility at GTRI's off-campus research site fifteen miles northwest of Atlanta. This multimillion-dollar complex can accommodate a variety of antenna and radar cross-section measurements. It is now one of the leading facilities of its kind in the United

States and the largest affiliated with any university. The facility includes a far-field antenna range, a look-down radar cross section range with a heavy-duty target turntable, and a rooftop radar test and calibration range.

Telephone: (404) 894-3400
Fax: (404) 894-5283
Web: www.gtri.gatech.edu

Kent Ridge Digital Laboratories
21 Heng Mui Keng Terrace
Singapore 119613

The KRDL Mission is seeding high-value companies that have innovative technologies and persuasive business models.

KRDL was formed early in 1998 by the merger of two leading Information Technology research institutes in Singapore. KRDL quickly established itself as one of the most dynamic software laboratories in Asia. In the short space of two and a half years, it was directly responsible for ten spin-offs founded by its staff utilizing KRDL technologies.

Telephone: (65) 874-7588
Fax: (65) 775-9923
Web: www.krdl.org.sg

Midwest Research Institute (MRI)
425 Volker Boulevard
Kansas City, Missouri 64110-2299

For more than a half century, MRI has built its reputation applying expert research skills to find solutions for problems facing society. Born out of the desire to attract war contracts to bolster the Midwestern economy, MRI was established in 1944 with a mission to supply needed research for industry and to encourage programs using regional resources. But work soon expanded far beyond war-related and postwar conversion projects and far beyond only regional concerns.

Today MRI is an internationally acclaimed center for applied research and technology development. Since its inception, MRI scientists and engineers have served more than 5,000 clients throughout the world. These accomplishments range from pioneering efforts in environmental and cancer research to cutting-edge work in drug development and high-precision automation technology.

Telephone: (816) 753-7600
Fax: (816) 753-8420
email: info@mriresearch.org
Web: www.mriresearch.org

MIT Media Laboratory
MIT Building E15, The Wiesner Building
20 Ames Street
Cambridge, Massachusetts 02139

The Media Laboratory provides a unique environment for exploring basic research and applications at the intersection

of computation and the arts. Areas of research include software agents; machine understanding; how children learn; human and machine vision; audition; speech interfaces; wearable computers; affective computing (a new branch of computing that relates to, arises from, or deliberately influences emotion); advanced interface design; tangible media; object-oriented video; interactive cinema; work in various forms of digital expression, from text to graphics, to sound; and new approaches to spatial imaging, nanomedia, and nano-scale sensing.

The Media Laboratory comprises both a degree granting academic program and a research program. The Laboratory's faculty and senior research staff number approximately 30. Another 80 staff members also support the Laboratory's research, facilities, and administration.

Telephone: (617) 253-0338
Fax: (617) 258-6264
Web: www.media.mit.edu

Research Triangle Institute (RTI)
PO Box 12194
Research Triangle Park, North Carolina 27709-2194

Research Triangle Institute is dedicated to improving the human condition through multidisciplinary research, development, and technical services that meet the highest standards of professional performance.

Universities in North Carolina founded RTI in 1958 as the first scientific organization in, and centerpiece of, Research Triangle Park. Headquartered on a 180-acre campus, RTI's North Carolina facilities include more than 725,000 square feet of laboratory and office space. In addition, RTI has research offices in eight other U.S. cities, and in three other countries.

RTI is an independent organization dedicated to conducting innovative, multidisciplinary research that improves the human condition. With a worldwide staff of more than 1,800 people, RTI is active in health and medicine, environmental protection, technology commercialization, education, and decision support systems.

The energy, enthusiasms, entrepreneurship, and continuing quest for excellence of the people at RTI have provided a rich heritage for the Institute's future. As staff members take all steps possible toward accomplishing the Center's mission to improve the human condition, they adhere to the values that have been the foundation of RTI throughout its history: integrity, excellence, innovation, respect for the individual, fiscal responsibility, and respect for the Institute.

Telephone: (919) 485-2666
Fax: (919) 541-5985
Web: www.rti.org

Sarov Open Computing Center
Sarov N. Nizhny
Novgorod 602190
Russia

Under the auspices of the Department of Energy's Russian Nuclear Cities Initiative, the Sarov Open Computer Center (SOCC) was established in Sarov, Russia, about 250 miles southeast of Moscow and the home of the All-Russia Research Institute of Experimental Physics (VNIIEF). The Nuclear Cities Initiative provided start-up investment of about $500,000 in computer hardware and software, including modern scientific workstations plus a Linux cluster.

SOCC provides a mechanism for the Western private business and industrial sector to have access to the world-class applied mathematics, modeling, and simulation expertise that exists within VNIIEF. SOCC also helps open doors for the VNIIEF scientists to the private sector and helps them gain experience in marketing and business relations in order to strengthen and build a sustainable economic base for the city of Sarov.

The expertise of the SOCC scientists is in the areas of applied mathematics and computational research. Initial application areas draw on expertise in developing new mathematical algorithms, modernizing existing algorithms, and optimizing computer codes to take advantage of modern computer architectures such as parallel processing.

Telephone: 7 831 30 40995
Fax: 7 831 30 53808
Web: www.cisa.lanl.gov/ic2conf

Southern Research Institute (SRI)
2000 Ninth Avenue South
P.O. Box 55305
Birmingham, Alabama 35255-5305

Southern Research Institute is an independent, not-for-profit center for scientific research with a staff of nearly 600, including scientists, technical, and staff support personnel. In late 1999, the Institute affiliated with the University of Alabama at Birmingham. Both institutions are recognized leaders in many fields of scientific inquiry. The Institute works under contract for both public and private sector clients.

Southern Research Institute was chartered on the eve of World War II, largely through the efforts of Thomas Wesley Martin, at the time president of Alabama Power Company. Martin believed that scientific research of high quality, applied to the needs of a modern industrial economy, would be critical to the future progress of the South.

The Institute has grown to include twenty-five buildings at its main Birmingham campus, an engineering center in suburban Birmingham, and facilities in Frederick, Maryland; Research Triangle Park, North Carolina; Annandale, Virginia; Anniston, Alabama; and Ft. Leonard Wood, Missouri. SRI scientists, technicians, and support staff have earned a worldwide reputation for excellence, their work marked by a culture of cooperation and belief in a better future through science.

Telephone: (205) 581-2000. Or: 800-967-6774
Fax: (205) 581-2726
email: southern@sri.org
Web: www.southernresearch.com

Southwest Research Institute (SwRI)™
6220 Culebra Road
PO Drawer 28510
San Antonio, Texas 78228-0510

Southwest Research Institute (SwRI) is an independent, nonprofit, applied engineering and physical sciences research and development organization founded in 1947 by Thomas Baker Slick Jr., an oilman-rancher-philanthropist who believed that science and technology are the keys to a better world. Eleven technical divisions use multidisciplinary approaches to problem solving. The Institute occupies a campus of 1,200 acres.

SwRI is an independent, nonprofit, applied engineering, and physical sciences research and development organization dedicated to technology development and transfer. Approximately 2,700 employees work in more than 1.7 million square feet of laboratories, test facilities, workshops, and offices, on contract work for industry and government clients. Program development offices are located in Houston, Detroit, and Washington, D.C.

Telephone: (210) 684-5111
Fax: (210) 522-3496
Web: www.swri.org

Stanford Research Institute (SRI)
333 Ravenswood Avenue
Menlo Park, California 94025-3493

Since its formation in 1946, SRI's mission has remained the same: to promote and foster the application of science in the development of commerce, trade, and industry and in the improvement of the peace and prosperity of society. SRI's researchers, scientists, technologists, and consultants excel at creating, applying, and bringing new discoveries to market.

SRI's main campus in Menlo Park, California, includes more than 250,000 square feet of research labs. In addition, there are fifteen SRI regional, project, and field offices around the world from Tokyo to Boston and Cambridge to Seoul. A staff of more than 1,400 people provide research and innovation services in pure and applied physical sciences, information technology, pharmaceutical discovery, biochemical and biopharmaceutical development, engineering sciences, other areas of technological innovation, and policy issues.

SRI is committed to moving R&D initiatives from the lab into the marketplace and to helping companies address the ever-increasing market pressures of faster technology cycles, growing technology complexity, demanding consumers, and heightened global competition.

SRI is a nonprofit scientific research institute. Two wholly owned subsidiaries, SRI Consulting and Sarnoff Corporation, are for-profit corporations.

Telephone: (650) 859-2000
Fax: (650) 326-5512
email: inquiry.line@sri.com
Web: www.sri.com

Syracuse Research Corporation (SRC)
6225 Running Ridge Road
North Syracuse, New York 13212

SRC was created by Syracuse University in 1957. In the early 1970s, the Corporation spun off from the University to become a totally independent organization. For over 40 years, SRC has supported a broad range of federal government organizations and agencies, and has developed a national reputation in a wide array of technology areas. The Corporation's activities are also focused on initiatives associated with economic development, technology innovation, environmental quality, and academic-to-industry coupling. Commercially, SRC experienced rapid growth in projects, associated with the application of information technologies. SRC employs approximately 340 people in eleven locations across the United States.

Telephone: (315) 452-8000
Fax: (315) 452-8100
Web: www.syrres.com

APPENDIX B

HARC CENTERS AND LABORATORIES

HARC Centers and Laboratories are collaborative institutions linking academic, industry, and government partners to develop new research technology into products and services brought to market for the benefit of society.

George and Cynthia Mitchell Center for Sustainable Development
Tel: (281) 363-7918

This Center works to improve the quality of life in Houston, in our hemisphere, and in our world. For 25 years the Center has tackled difficult and complex issues related to policy and resource use, among them water resources and quality, population growth, air pollution, global warming, immigration, electric power, transportation, alternative fuels, acid rain, and corporate strategies leading to sustainability. The Center has organized more than 20 major conferences and workshops and published a number of award-winning books and reports.

Astroparticle Physics Group
Tel: (281) 363-7955

This Group is dedicated to cracking the cosmic code, first by exploring the origin of space and time, black hole dynamics, and the unification of quantum mechanics and gravity, and then, by building and studying supersymetric unified models of elementary particle physics. The group is also developing a new theory of brain function prompted by advances in mesoscopic quantum physics.

DNA Technology Laboratory
Tel: (281) 364-4058

This laboratory was created in 1991 to build a leading research program in the development and application of DNA chips for the rapid detection of genetic alterations. Research at HARC has involved the use of DNA technologies for the detection of the breast cancer susceptibility genes *BRCA1* and *BRCA2*, the diagnosis of retinoblastoma in children, and the diagnosis of antibiotic-resistant strains of tuberculosis.

Environmental Information Systems.
Tel: (281) 364-6003

This laboratory uses advanced computer technologies to integrate, visualize, and analyze Laboratory spatial data for a variety of earth resources related projects–from mapping

hazardous waste sites to developing sensors for environmental monitoring. The laboratory provides three critical areas of expertise: sensor design to detect targets, software development to integrate information systems technologies, and environmental/earth science applications.

Center for Fuel Cell Research and Application

Tel: (281) 363-7929

This Center conducts demonstration projects and applied research focused on promising fuel cell technologies. The Center's core program focuses on the application of proton-exchange-membrane (PEM) fuel cells in stationary and mobile applications. A 3-year, $7 million project seeks to test and determine the various conditions under which fuel cells can be put to use as a clean, reliable, and affordable energy source.

Geotechnology Research Institute

Tel: (281) 364-6061

This Institute was created in 1985 by the Texas Legislature to carry out advanced research to enhance methods of oil and gas exploration, to develop new technology to meet growing market demands, and to make the results of this research available for the benefit of the energy industry. Work is focused on geochemistry and rock physics.

Technology Development Laboratory
Tel: (281) 364-4039

This laboratory designs and fabricates technology prototypes and provides testing services. The laboratory is currently building state-of-the-art LIDAR systems for the digital mapping industry. Other studies involve superconducting magnetic energy storage systems, associated vacuum and electronics, cryogenic material and component testing, electric power transmission analysis, and related engineering projects.

APPENDIX C

EXTRACTS FROM INTELLECTUAL PROPERTY POLICIES

The following extracts are from the Intellectual Property Policies of two Research Centers: The Houston Advanced Research Center (HARC), and The University of Oklahoma. The extracts describe the organizations' technology purposes, the ownership of technology discovered by their research, and the distribution of revenues from the application of the technology.

HOUSTON ADVANCED RESEARCH CENTER (HARC)

PARAGRAPH 1. PURPOSE:

To promote the progress of science and the useful arts by stimulating the development of ideas, discoveries, inventions, information, data, works of authorship, and other intellectual

creations by HARC personnel; to utilize the benefits of patent, copyright and all other intellectual property rights systems; and to encourage other research institutions to collaborate with HARC on development of ideas, discoveries, inventions, information, data, works of authorship, and other intellectual creations.

PARAGRAPH 3. POLICY:

Unless otherwise provided by action of the Board of Directors, any and all Technology within the Scope of this Policy are and shall be the property of HARC. HARC shall be the owner of all of the Participant's worldwide right, title, and interest in such Technology, including all royalties and revenues derived therefrom. HARC shall be the owner of not only the physical things in which the Technology is embodied but also of all of the intellectual property rights therein provided by any and all jurisdictions throughout the world, including the right of first publication, all rights of copyright, and all rights to file for, obtain, and maintain patent and other industrial rights. Each Participant hereby assigns and agrees to assign his or her worldwide right, title, and interest in the Technology to HARC in accordance with this Policy and to assist HARC and its nominee, at any time, in the protection of HARC's worldwide right, title, and interest in and to the Technology, including without limitation, the execution of all formal assignment documents requested by HARC or its nominee and the execution of all lawful oaths and applications for applications for patents and registration of copyright in the United States and foreign countries. To the extent this ownership Policy is inconsistent with

the terms of any applicable agreement with a third-party sponsor or provider of funds, HARC's agreement with such sponsor shall control.

PARAGRAPH 6. DISTRIBUTION OF ROYALTY AND LICENSING INCOME:

a) Royalty and other income resulting from the licensing or other commercialization of the Technology will be distributed annually, as follows:

(i) First, fifteen percent (15%) of such annual income shall be retained by HARC to support the general operating costs of the institution. The manner in which this fifteen percent is distributed within HARC shall be with the approval of the President.

(ii) The remaining annual income shall be retained by HARC until all costs directly attributable to the set of ideas, discoveries, inventions, improvements, data, original works of authorship, or other intellectual creation being commercialized have been recovered (this includes, but is not limited to, patent filing fees, preparation of license agreements, litigation, interference, administrative, legal, and marketing costs). In addition, HARC may in its discretion retain reasonable, affiliated project development costs that were paid for utilizing HARC's discretionary funds (as distinguished from restricted funds received by HARC from a sponsor).

(iii) After HARC recovers the fifteen percent specified in subparagraph (i) and all of the reimbursements specified in subparagraph (ii), remaining annual income will be distributed

according to the following sliding scale based upon cumulative income to HARC (including equity consideration):

$0 - $4,000,000	50% to HARC and 50% to inventor(s)
$4,000,001 - $12,000,000	75% to HARC and 25% to inventor(s)
$12,000,001 and above	90% to HARC and 10% to inventor(s)

The sum specified in this subparagraph **(iii)** shall be distributed annually to the Participants as soon as practical after the close of the fiscal year during which the income was received. Income payable to a Participant shall survive termination of affiliation with HARC and in the event of death of the Participant shall inure to his/her estate.

Income to HARC shall be used for research programs and activities that are in furtherance of its scientific research mission.

UNIVERSITY OF OKLAHOMA

PREAMBLE.

The people of the State of Oklahoma may reasonably expect that their investments in the University of Oklahoma will create new industry and enhance existing industry within the State and Nation. Such new industry creates greater employment opportunities for citizens of the State and the Nation and an improvement in their standard of living.

The creation and development of intellectual property at the University encourages new business and is key to creating strong University and industry partnerships. It is the

responsibility of University employees to disclose intellectual property and to foster an entrepreneurial attitude within the work force by involving students in the creation of intellectual property. Intellectual property development shall be pursued in concert with, but subject to, the University's principal responsibilities of education and knowledge creation.

Therefore, it is in the best interest of the University to adopt a policy that encourages disclosure of discoveries and inventions and rewards such creative activity. To do so, the University policy must insure inventors a share in any financial success enjoyed by the University through the creation and commercialization of intellectual property. The basic objectives of the University's policy concerning discoveries and inventions include the following:

a) To maintain the University's academic policy of encouraging research, publication, and scholarship independent of potential gain from royalties or other income.
b) To make patented materials created pursuant to University objectives available in the public interest under conditions that will promote their effective utilization and commercialization.
c) To provide adequate incentive and recognition to faculty and staff through proceeds derived from their works.

PATENTS. PARAGRAPH 1. OWNERSHIP:

1.1 All discoveries and inventions, whether patentable or unpatentable, and including any and all patents (domestic and foreign) based thereon and applications for such patents,

which are made or conceived by any member of the faculty, staff, or student body of The University of Oklahoma, either in the course and/or scope of employment for the University of Oklahoma or substantially through the use of facilities or funds provided by or through the University shall be owned by and be the property of the Board of Regents of the University of Oklahoma except as described below.

1.2 The University Vice President for Technology Development may in collaboration with the appropriate originating campus Officers, negotiate ownership of discoveries/inventions with research sponsors when it is in the best interest of the University to do so. Otherwise, all rights are as described below.

1.5 All rights in and to discoveries and inventions described in Paragraph 1.1 shall be disclosed to and assigned to the Board of Regents of the University of Oklahoma as a specific condition of employment with the University and admission to and/or attendance at the University. Faculty, staff, and students shall execute any and all documents the University deems reasonably necessary to evidence such ownership, meet its legal obligations and effect patent protection, domestic and foreign, for the University or its nominee. All costs involved in obtaining and maintaining patent protection shall be borne by the University or its nominee.

PARAGRAPH 2, REVENUE.

2.1 The gross revenues received by the University from the licensing, sale, or commercialization of a University discovery

or invention as described in section 1, will be distributed among the discoverer(s)/inventor(s), his/her/their primary department(s) and the University, in accordance with the following formula:

35% of gross revenue (which shall include, but not be limited to, cash and equity) to the University discoverer(s)/inventor(s);

The remaining 65% to be used to reimburse the University for out-of-pocket expenses that it has or shall incur in connection with, but not limited to, patent filing, prosecution, maintenance, and defense;

The remaining balance after expenses have been recouped will be distributed as follows:

31% to originating college(s), half of which to go to the originating department

7% to the President's discretionary fund

7% to the campus Vice President for Research

25% to OTD to apply to operational expenses with a pro rata share to go to the originating campus (at least 80%) Office of Technology Development

30% to the Growth Fund maintained for each originating campus

AUTHOR BIO

W. ARTHUR "SKIP" PORTER, PH.D.

Dr. Porter is University Vice President for Technology Development at the University of Oklahoma and Dean of the College of Engineering, and Secretary for Science and Technology Development for the State of Oklahoma. Under his leadership, the University's Office of Technology Development opened an incubator for high-tech start-up companies; part of a new technology research park. In the College of Engineering he has added technology transfer to the curriculum to produce graduates who not only get jobs, but who will create new jobs.

Previously, Dr. Porter was President and CEO of the Houston Advanced Research Center (HARC). Before joining HARC he served as director and CEO of the Texas Engineering Experiment Station at Texas A&M University where he was a tenured professor of electrical engineering and Director of A&M's Institute for Solid State Electronics. Earlier, he was a member of the technical staff of Texas Instruments where he developed the first fully automated

system for manufacturing integrated circuits. For more than two decades, he has been recognized as an international authority on technology commercialization and the management of collaborative projects, and his advice is regularly sought by government, industry, and academic institutions worldwide.

His awards and honors include NASA's Certificate of Research Recognition, and the Technology Leadership Award from the American Society for Engineering Management.

Dr. Porter is a Fellow of the IC^2 Institute. He serves on several Boards, and is a corresponding member of the Swiss Academy of Engineering Sciences.

Dr. Porter received his BS and MS degrees in physics from the University of North Texas, and his Ph.D. in interdisciplinary engineering from Texas A&M.

Dr. Porter would like to hear your comments on the ideas presented in this book. He can be contacted at his email address: porter@ou.edu

ABOUT THE IC² INSTITUTE

The IC² Institute at the University of Texas focuses primarily on technology commercialization, entrepreneurship, and innovative education to accelerate wealth creation and new ways of sharing that wealth. Founded in 1977, The IC² Institute's mission is to facilitate wealth creation and innovative prosperity sharing through three broad program areas aimed at improving technology commercialization. These include:

1 Laboratory-to-Market Programs that help us to enhance and accelerate technology commercialization of research emanating from university labs, corporate labs, and national labs;

2 Educational Programs that produce technology commercialization leaders who can commercialize new technologies effectively, as well as technology commercialization scholars who help us to understand this vital wealth creating commercialization process; and

3 Technopolis Building Programs that accelerate the socioeconomic development of new regions by organizing academic and government leaders with business,

civic, and social entrepreneurs to create vibrant high technology regions.

These programs are created and implemented with the help of IC² Global Partners and IC² Fellows. In addition to 25 Global Partners, The IC² Institute has over 230 IC² Fellows located around the world. IC² Fellows are an exceptional and diverse set of individuals from government, business, the non-profit sector, and academia who leverage and extend the Institute's worldwide programs.

IC² Global Partners work with the Institute on technology commercialization projects, along with related initiatives involving high technology entrepreneurship, distance education, emerging technologies, innovative organizational strategies, technopolis creation, and constructive capitalism.

The IC² Fellows Book Series is dedicated to these "thought and action leaders." The series presents the "cutting edge" work of selected Fellows in areas that relate to the Institute's overarching interest in technology commercialization. Related interests include high technology entrepreneurship, distance education, emerging technologies, innovative organizational strategies, technopolis creation, and constructive capitalism.

The Knowledge Seekers is the first of our IC² Fellows Books. Many people collaborated to create this book. We would like especially to thank and congratulate the author, Dr. W. Arthur Porter, a distinguished IC² Fellow. And we express our thanks and appreciation to Dr. Robert Ronstadt for conceiving and directing the IC² Fellows Book Series. For the editing, design, and production of this book we

express our thanks to Dr. Beckie McCleery, Rebecca Ronstadt, Bill Christopher, Dr. Kate Mackie, Luana Richards, Michael Aaron, Tink Hardwick-Erdman, Jan Haseman, Anitra Blackford, and Dick Chase for their contributions.

You can learn more about The IC² Institute by contacting us by phone 512.475.8900, or via our website at: www.ic2.org

Published by The IC^2 Institute and written by Dr. W. Arthur "Skip" Porter, The Knowledge Seekers is the first in an exciting and innovative new book series written by exceptional high tech "thoughtleaders and actionleaders" in government, business, the non-profit sector and academia. Experts in econometrics, regional economic development, business strategy, marketing, technology transfer and commercialization, chaos theory, creative and innovative management, alliance building, globally-networked entrepreneurship, electronic commerce, and other disciplines, IC^2 Fellows are at the intellectual center of the Institute's global community.

In his book, The Knowledge Seekers, Dr. Porter describes how "Centers for the Performing Sciences" are formed through the collaboration of businesses, universities and government to speed new research and development, and driving today's and tomorrow's new wealth creation and prosperity sharing. Dr. Porter's book and the "Centers for the Performing Sciences" serves as a model for all "seekers of knowledge."

"In The Knowledge Seekers. Dr Skip Porter brings a realistic, innovative and inspiring strategy for succeeding in the next phase of the high tech business revolution. His insights aren't just theory but useful applications already hard at work redefining how industry, government and academia partner to create thriving economies."

Mike Maples, Executive Vice President, Retired.
Worldwide Products and Marketing, Microsoft Corporation

"I have a very high regard for Skip Porter's abilities as a researcher, as a teacher, and as a manager of technology programs. He has developed a successful approach to bring industry and academia together to insure the best technology reaches the marketplace and benefits all of society."

Dr. Jack Kilby, Creator of the Integrated Circuit.
Winner of the 2000 Nobel Prize in Physics.

Dr. W. Arthur "Skip" Porter is University Vice President for Technology Development at the University of Oklahoma, Dean of the College of Engineering, and Secretary for Science and Technology Development for the State of Oklahoma. Previously he headed the Houston Advanced Research Center, one of the pioneering Centers for the Performing Sciences. His book describes the ideas from his experience that best apply research discoveries to human progress.

The IC^2 Fellows Book Series is published by The IC^2 Institute, an international, trans-disciplinary "think and do" tank. The Institute links technology, entrepreneurship, and education to foster sustainable social and economic development around the world. At the intellectual center of the Institute's global community is the Fellows Program. IC^2 Fellows, more than 230 worldwide, include Nobel Laureates, Medal of Technology winners, Fortune 500 executives, and other leaders. IC^2 Fellows support and extend the Institute's worldwide programs. The IC^2 Fellows Book Series is dedicated to these distinguished thought and action leaders, many of whom will be among our authors.

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